**IN THE UNITED STATES DISTRICT COURT
EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION**

(1) SENSORMATIC ELECTRONICS CORPORATION	§	
Plaintiff,	§	**Civil Case No. 2-04CV-167 TJW**
v.	§	**JURY DEMANDED**
(1) WG SECURITY PRODUCTS, INC. and (2) EAS SENSORSENSE, INC.	§	
Defendants.	§	

ORIGINAL COMPLAINT

Plaintiff Sensormatic Electronics Corporation ("Sensormatic"), by and through the undersigned attorneys, hereby files this Complaint requesting damages and injunctive relief upon personal knowledge as to its own acts and circumstances and upon information and belief as to the acts and circumstances of others as follows:

PARTIES

1. Plaintiff Sensormatic is a Nevada corporation, with its principal place of business at 950 Yamato Road, Boca Raton, Florida 33431. Among other things, Sensormatic is engaged in the engineering and manufacturing of Electronic Article Surveillance Tags ("EAS Tags") and other surveillance equipment.

2. Defendant WG Security Products, Inc. ("WG") is a California corporation, believed to have a principal place of business of 3031 Tisch Way, Suite 602, San Jose, CA 95128. Service of process may be made on WG's registered agent: Xiaohui Yang at 161 San Lazaro Ave., Sunnyvale, CA 94086.

3. Defendant EAS Sensorsense, Inc. ("Sensorsense") is a California corporation, believed to have a principal place of business of 13165 Sherman Way, North Hollywood, CA 91605. Service of process may be made on Sensorsense's registered agent: Jules Rothman at 15233 Ventura Blvd., Suite 1100, Sherman Oaks, CA 91403-2387.

4. WG and Sensorsense are collectively referred to herein as "Defendants."

JURISDICTION AND VENUE

5. This action arises under the Patent Laws of the United States, 35 U.S.C. § 101 *et seq.* and is being brought to redress the infringement of United States Patent Nos. 5,426,419 (the "'419 Patent"), 6,118,378 (the "'378 Patent"), and 6,700,490 (the "'490 Patent") owned by Sensormatic, copies of which are attached as Exhibits "1," "2," and "3" and incorporated herein by reference. Accordingly, subject matter jurisdiction over this cause of action is conferred upon this Court pursuant to 28 U.S.C. §§ 1331 and 1338.

6. As alleged herein, because one or more of the Defendants have offered products for sale within this judicial district that infringe the '419, '378, and/or '490 Patents, this Court has personal jurisdiction over Defendants, and venue is proper in this judicial district under 28 U.S.C. §§ 1391(b), (c) and 1400(b).

COUNT 1

INFRINGEMENT OF U.S. PATENT NO. 5,426,419

7. Sensormatic incorporates and realleges the foregoing paragraphs as if fully set forth at length.

8. On January 14, 1993, Thang T. Nguyen, Elbert W. Dooley, Jr., Hans P. Witzky, and Norman Hansen filed an application for a United States patent directed to a

"SECURITY TAG HAVING ARCUATE CHANNEL AND DETACHER APPARATUS FOR SAME." On June 20, 1995, the United States Patent and Trademark Office duly and legally issued the Nguyen et al. application as the '419 Patent.

9. Sensormatic is the owner of all right, title, and interest in and to the invention of the '419 Patent by assignment.

10. Upon information and belief, Defendants are making, using, offering to sell, and selling a product known as the "Super-Sensor" ("Super-Sensor") that infringes one or more claims of the '419 Patent.

11. Accordingly, Defendants have profited through infringement of the claims of the '419 Patent. As a result of Defendants' unlawful infringement of the '419 Patent, Sensormatic has suffered, and will continue to suffer, damages.

12. Upon information and belief, Defendants' acts of infringement herein have been made with full knowledge of Sensormatic's rights in the '419 Patent. Such acts constitute willful infringement and make this case exceptional pursuant to 35 U.S.C. §§ 284 and 285 and entitle Sensormatic to enhanced damages and reasonable attorneys' fees.

13. Upon information and belief, Defendants intend to continue their unlawful infringing activity unless enjoined by this Court.

COUNT 2

INFRINGEMENT OF U.S. PATENT NO. 6,118,378

14. Sensormatic incorporates and realleges the foregoing paragraphs as if fully set forth at length.

15. On November 28, 1997, Brent F. Balch, Stephen W. Embling, and Ming-Ren Lian filed an application for a United States patent directed to a "PULSED

MAGNETIC EAS SYSTEM INCORPORATING SINGLE ANTENNA WITH INDEPENDENT PHASING." On September 12, 2000, the United States Patent and Trademark Office duly and legally issued the Balch et al. application as the '378 Patent.

16. Sensormatic is the owner of all right, title, and interest in and to the invention of the '378 Patent by assignment.

17. Upon information and belief, Defendants are making, using, offering to sell, and selling, within this judicial district and elsewhere, a product known as the "Mono-Guard" ("Mono-Guard") that infringes one or more claims of the '378 Patent.

18. Accordingly, Defendants have profited through infringement of the claims of the '378 Patent. As a result of Defendants' unlawful infringement of the '378 Patent, Sensormatic has suffered, and will continue to suffer, damages.

19. Upon information and belief, Defendants' acts of infringement herein have been made with full knowledge of Sensormatic's rights in the '378 Patent. Such acts constitute willful infringement and make this case exceptional pursuant to 35 U.S.C. §§ 284 and 285 and entitle Sensormatic to enhanced damages and reasonable attorneys' fees.

20. Upon information and belief, Defendants intend to continue their unlawful infringing activity unless enjoined by this Court.

COUNT 3

INFRINGEMENT OF U.S. PATENT NO. 6,700,490

21. Sensormatic incorporates and realleges the foregoing paragraphs as if fully set forth at length.

22. On March 22, 2002, Thomas J. Frederick filed an application for a United States patent directed to "DIGITAL DETECTION FILTERS FOR ELECTRONIC

ARTICLE SURVEILLANCE." On March 2, 2004, the United States Patent and Trademark Office duly and legally issued the Frederick application as the '490 Patent.

23. Sensormatic is the owner of all right, title, and interest in and to the invention of the '490 Patent by assignment.

24. Upon information and belief, Defendants are making, using, offering to sell, and selling, within this judicial district and elsewhere, their Mono-Guard product that infringes one or more claims of the '490 Patent.

25. Accordingly, Defendants have profited through infringement of the claims of the '490 Patent. As a result of Defendants' unlawful infringement of the '490 Patent, Sensormatic has suffered, and will continue to suffer, damages.

26. Upon information and belief, Defendants' acts of infringement herein have been made with full knowledge of Sensormatic's rights in the '490 Patent. Such acts constitute willful infringement and make this case exceptional pursuant to 35 U.S.C. §§ 284 and 285 and entitle Sensormatic to enhanced damages and reasonable attorneys' fees.

27. Upon information and belief, Defendants intend to continue their unlawful infringing activity unless enjoined by this Court.

JURY DEMAND

28. Plaintiff demands a trial by jury pursuant to Rule 38, Fed.R.Civ.P.

PRAYER FOR RELIEF

WHEREFORE, Sensormatic prays that it have judgment against Defendants for the following:

(1) A decree that the '419 Patent is infringed by the Super-Sensor, which is made, used, offered for sale, and/or sold by Defendants;

(2) A decree that the '378 Patent is infringed by the Mono-Guard, which is made, used, offered for sale, and/or sold by Defendants;

(3) A decree that the '490 Patent is infringed by the Mono-Guard, which is made, used, offered for sale, and/or sold by Defendants;

(4) A preliminary and permanent injunction enjoining and restraining Defendants and their officers, agents, servants, employees, and attorneys, and those in active concert or participation with them who receive actual notice of the order granting the injunction by personal service or otherwise, from making, using, offering to sell, selling, and importing into the United States any product, including the Super-Sensor, which falls within the scope of any claim of the '419 Patent;

(5) A preliminary and permanent injunction enjoining and restraining Defendants and their officers, agents, servants, employees, and attorneys, and those in active concert or participation with them who receive actual notice of the order granting the injunction by personal service or otherwise, from making, using, offering to sell, selling, and importing into the United States any product, including the Mono-Guard, which falls within the scope of any claim of the '378 Patent;

(6) A preliminary and permanent injunction enjoining and restraining Defendants and their officers, agents, servants, employees, and attorneys, and those in active concert or participation with them who receive actual notice of the order granting the injunction by personal service or otherwise, from making, using, offering to sell, selling, and importing into the United States any product, including the Mono-Guard, which falls within the scope of any claim of the '490 Patent;

(7) An award of damages;

(8) An award of exemplary damages;

(9) An award of all costs of this action, including attorneys' fees and interest; and

(10) Such other and further relief, at law or in equity, to which Sensormatic is justly entitled.

Respectfully submitted,

By: ______________________

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ATTORNEYS FOR PLAINTIFF
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CORPORATION

US005426419A

United States Patent [19]

Nguyen et al.

[11] Patent Number: 5,426,419

[45] Date of Patent: Jun. 20, 1995

[54] SECURITY TAG HAVING ARCUATE CHANNEL AND DETACHER APPARATUS FOR SAME

[75] Inventors: **Thang t. Nguyen**, Boca Raton; **Elbert W. Dooley, Jr.**, Lake Worth; **Hans P. Witzky**, Pompano; **Norman Hansen**, Highland Beach, all of Fla.

[73] Assignee: **Sensormatic Electronics Corporation**, Deerfield Beach, Fla.

[21] Appl. No.: **4,592**

[22] Filed: **Jan. 14, 1993**

[51] **Int. Cl.**[6] **G08B 13/14**; E05B 65/00

[52] **U.S. Cl.** **340/572**; 70/57.1

[58] **Field of Search** 340/572, 551; 70/57.1, 70/391, 416, 453, 454; 24/704.1, 704.2

[56] **References Cited**

U.S. PATENT DOCUMENTS

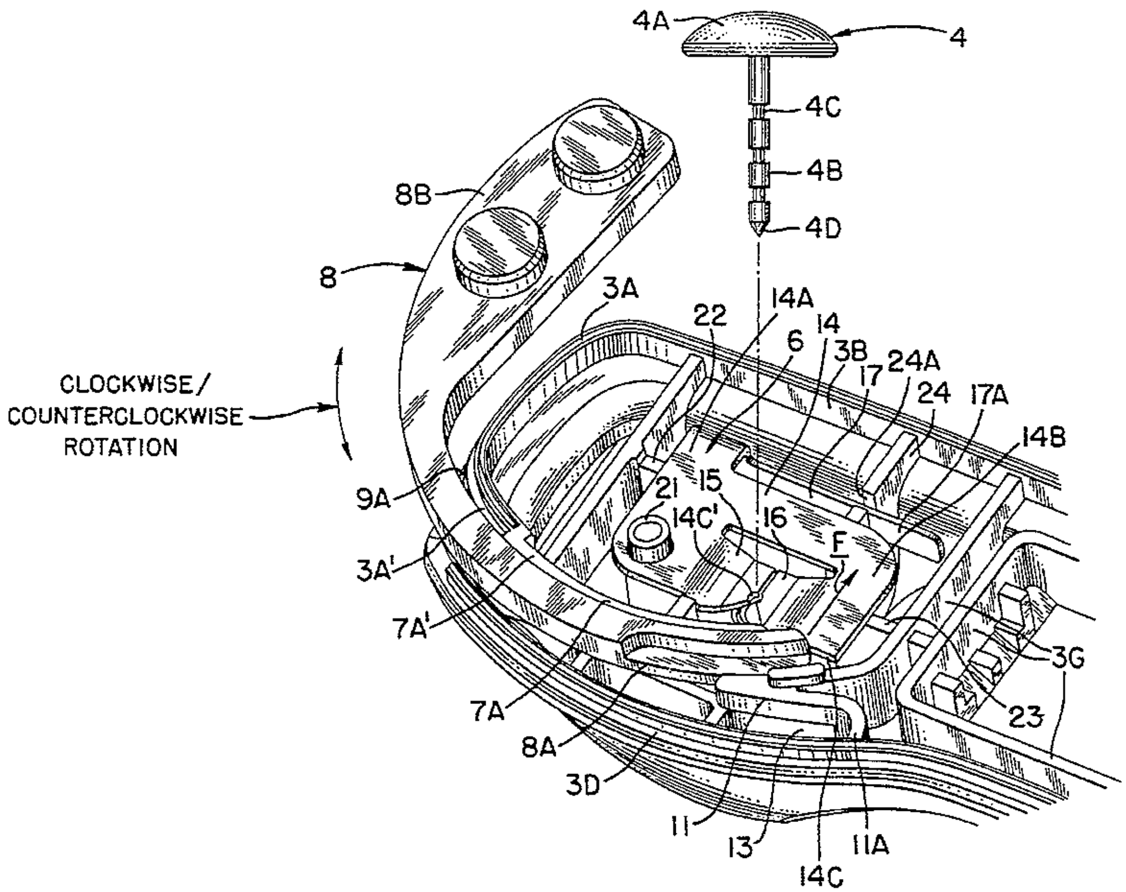
3,914,829	10/1975	Paskert	340/572 X
3,942,829	3/1976	Humble et al.	70/57.1
3,947,930	4/1976	Martens et al.	340/572
3,974,581	8/1976	Martens et al.	340/572
4,221,025	9/1980	Martens et al.	70/57.1
4,311,992	1/1982	DeChant	340/572
5,031,756	7/1991	Buzzard et al.	206/1.5
5,039,982	8/1991	Bruhwiler	340/572

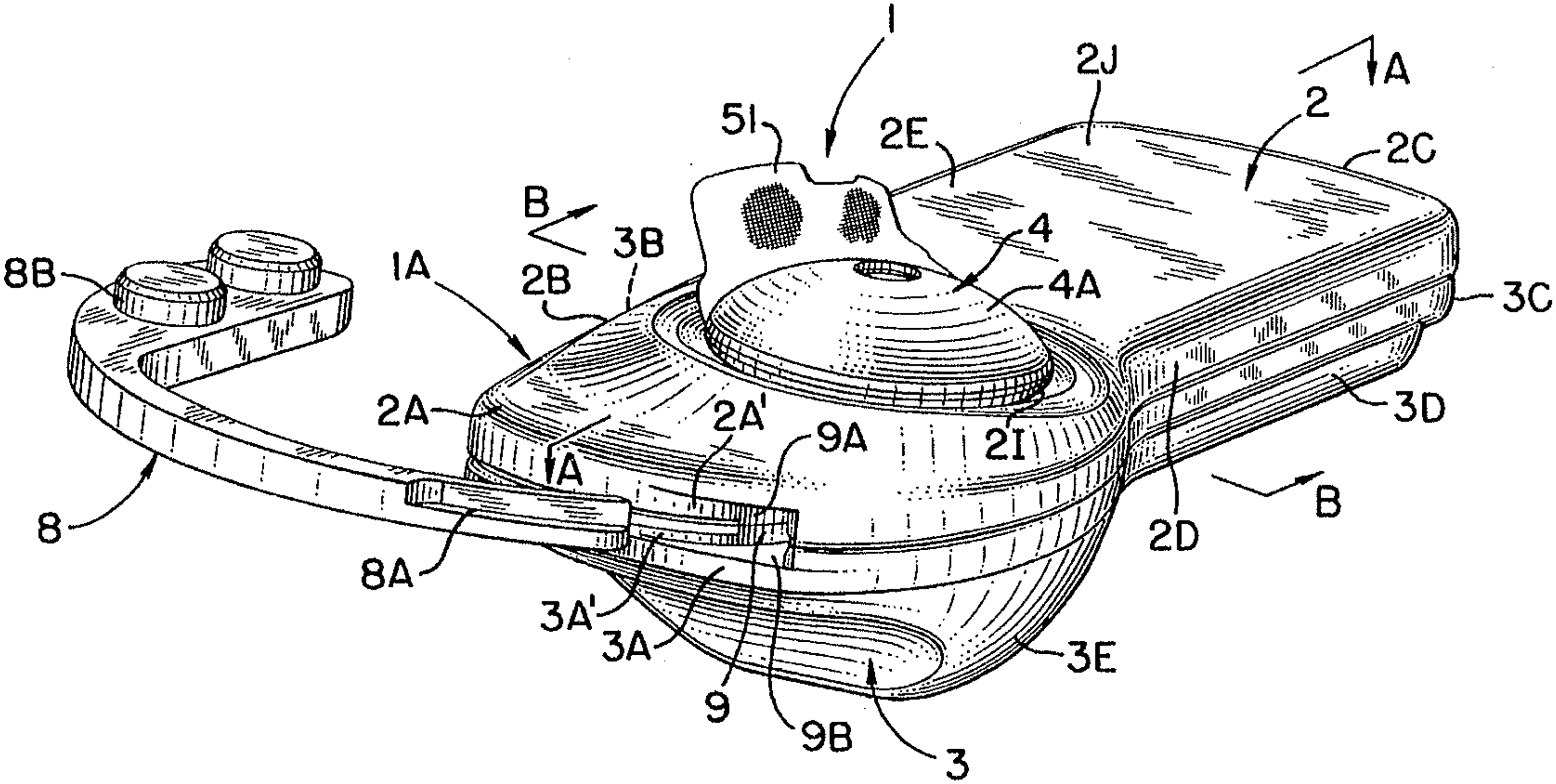
Primary Examiner—John K. Peng
Assistant Examiner—Thomas J. Mullen, Jr.
Attorney, Agent, or Firm—Robin, Blecker, Daley & Driscoll

[57] **ABSTRACT**

An EAS tag in which the tag is held to an article by an attaching assembly a part of which is releasably prevented from being withdrawn from the body of the tag. The tag body is provided with an arcuate channel through which an arcuate detacher probe can be guided for releasing the attaching assembly part. A spring clamp provides the releasable preventing function and includes jaws specifically adapted to respond to in-plane torsional forces provided by the arcuate probe which is moved through the arcuate channel by rotation to reach the spring clamp. Hand and power actuated detacher assemblies incorporating the arcuate probe are also provided.

46 Claims, 14 Drawing Sheets

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2J
A
2
2C
5I
2E
B
3B
4
8B
1A
2B
4A
3C
2A
2A'
9A
2I
3D
A
B
8
2D
8A
3A'
3A
3E
9
9B
3

FIG. 1

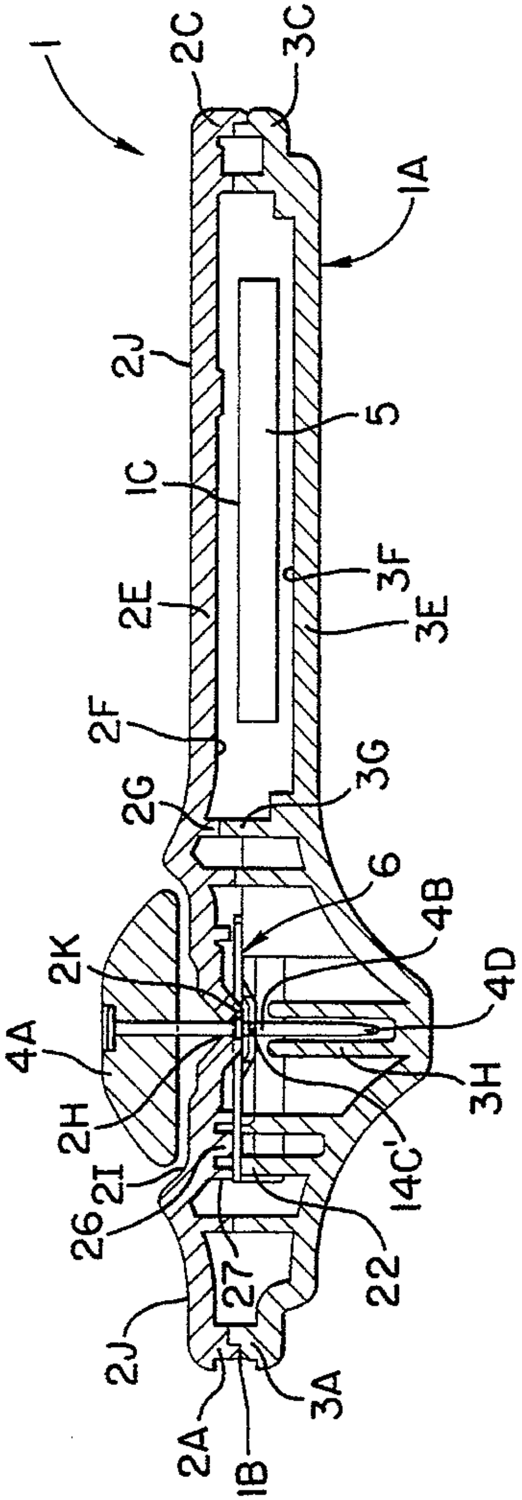

1
2C
3C
1A
2J
5
1C
3F
2E
3E
2F
3G
2G
6
4B
2K
4D
4A
2H
3H
14C'
2I
26
22
27
2J
3A
2A
1B

FIG. 2

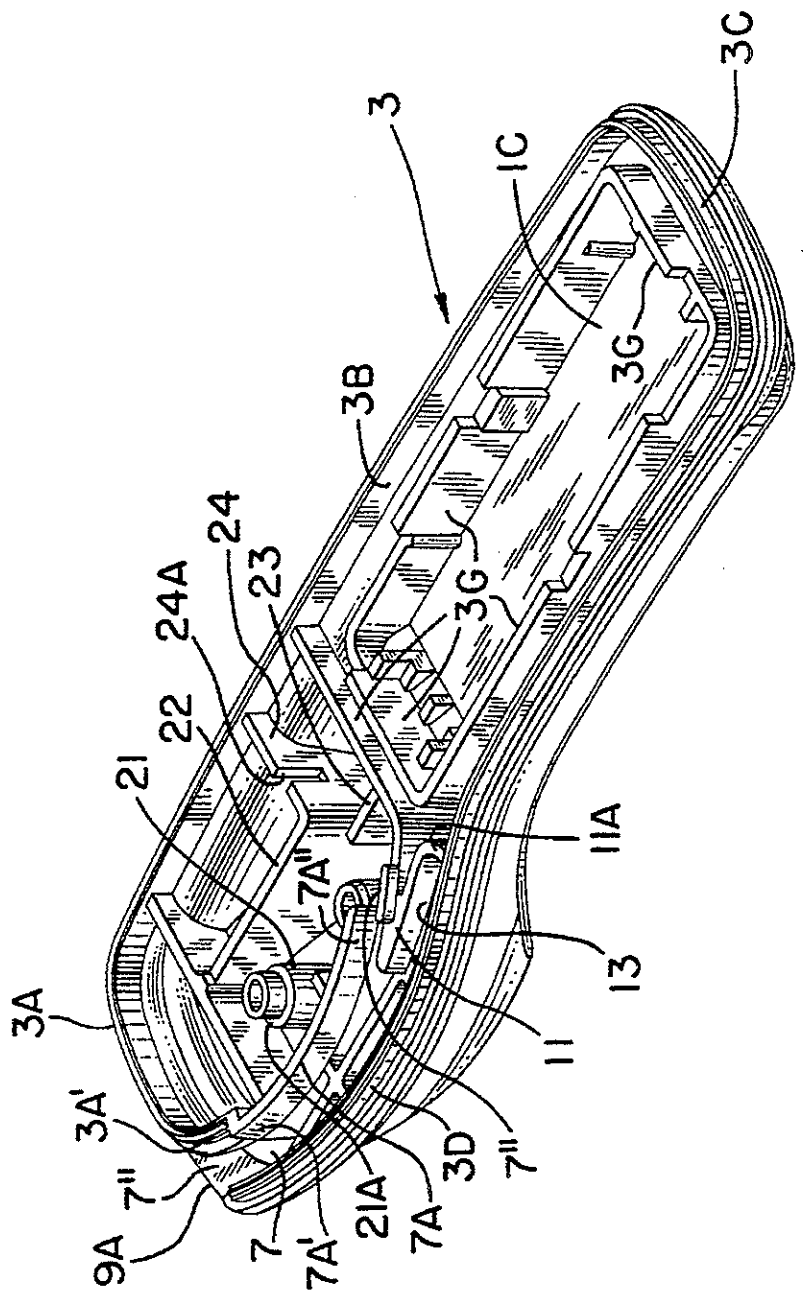


FIG. 3

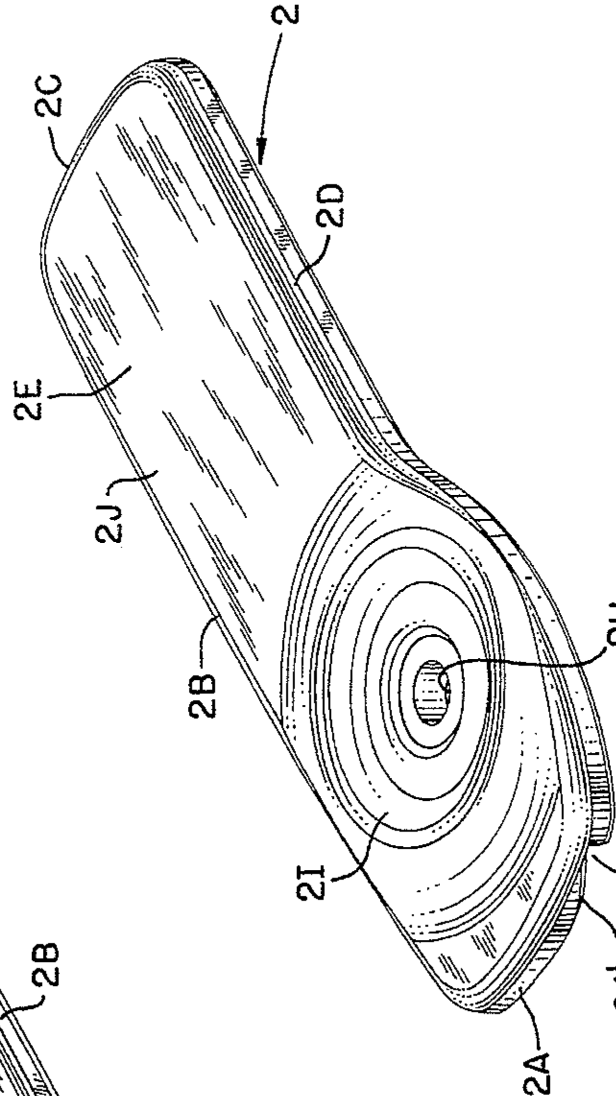

2
2C
2D
2E
2J
2B
2H
2I
9B
2A'
2A

FIG. 4B

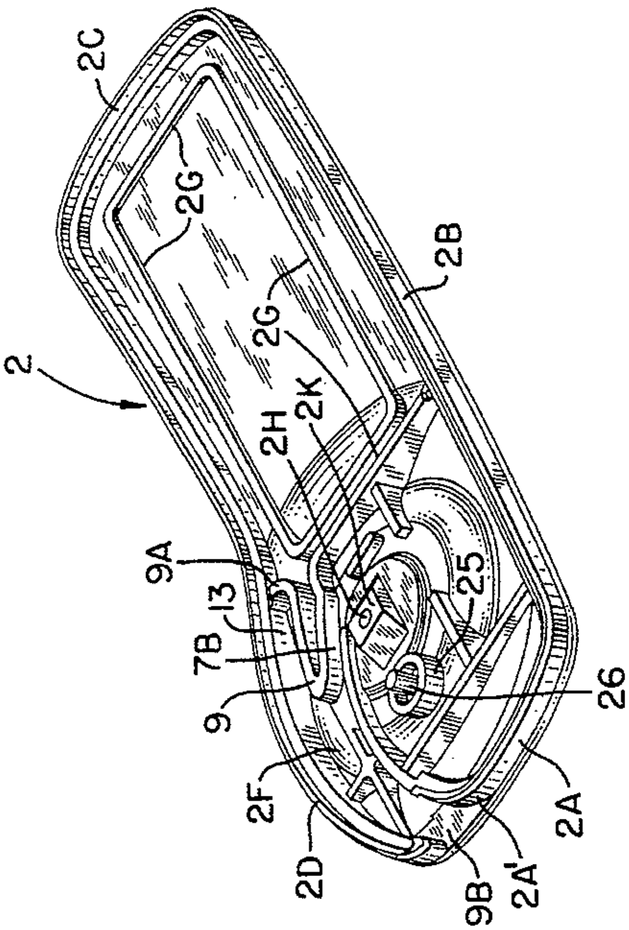
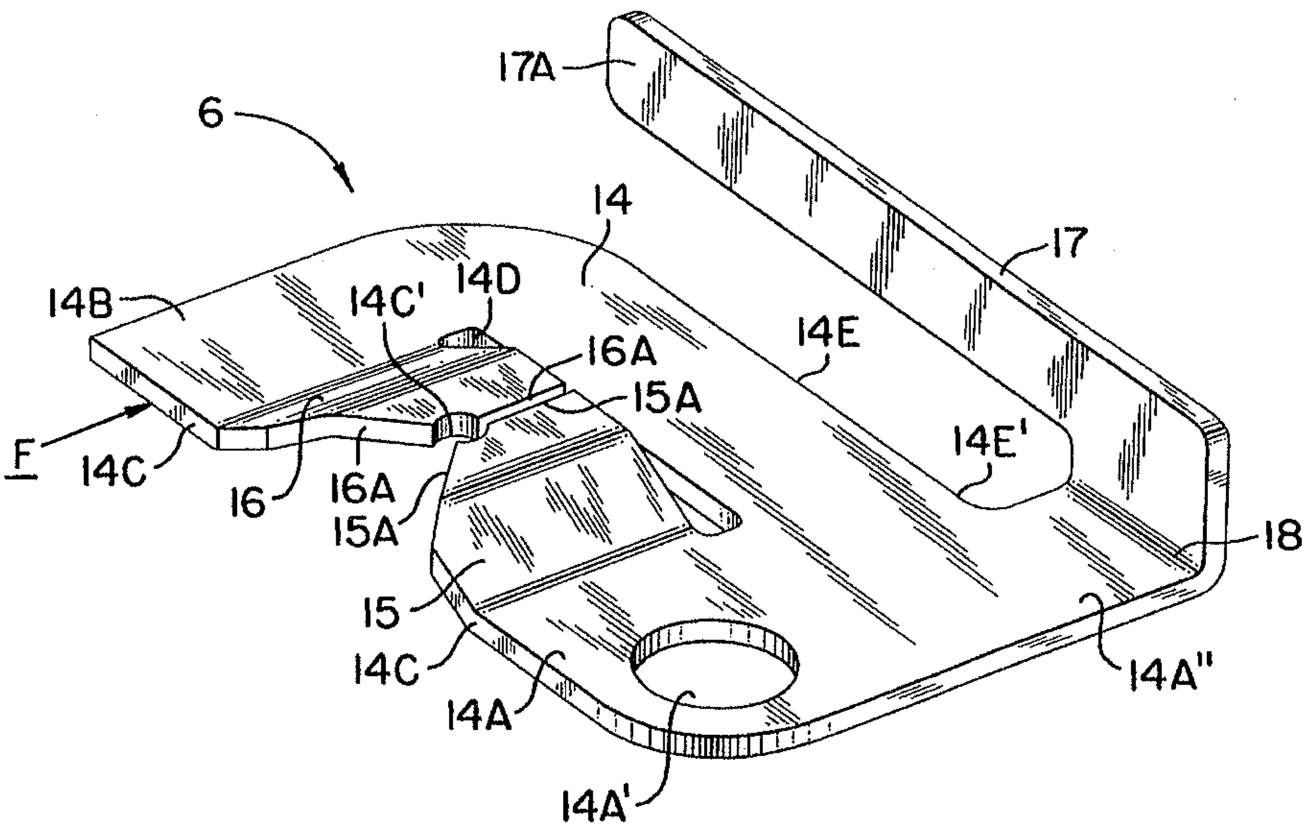

2C
2G
2B
2G
2
2K
2H
9A
25
13
7B
26
9
2F
2A
2D
9B
2A'

FIG. 4A



6
17A
14
17
14B
14D
14C'
16A
15A
14E
14E'
F
14C
16
16A
15A
18
15
14C
14A
14A"
14A'

FIG. 5

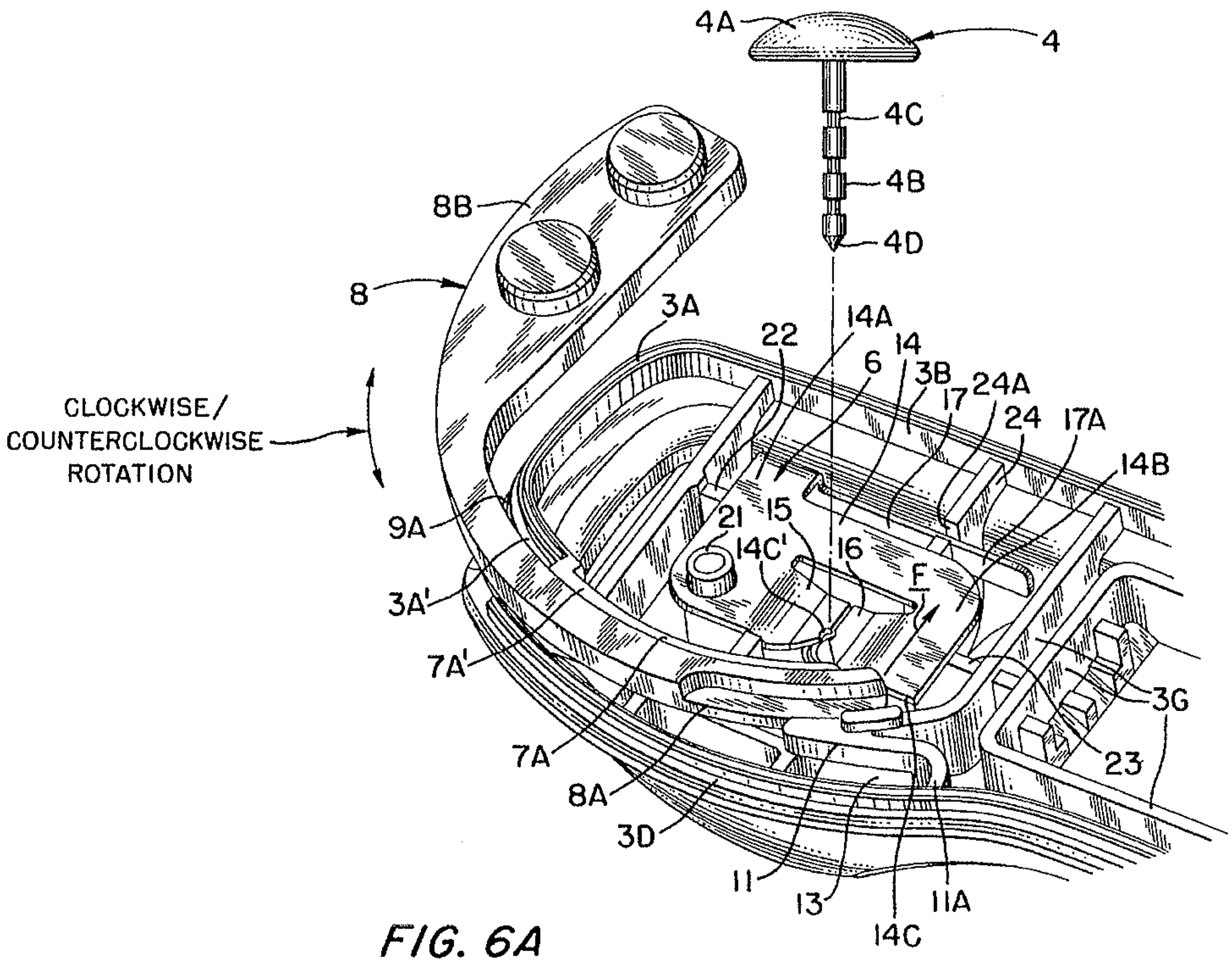

4A
4
4C
4B
4D
8B
8
3A
22
14A
14
6
3B
24A
17
24
17A
14B
CLOCKWISE/
COUNTERCLOCKWISE
ROTATION
9A
21
15
14C'
16
F
3A'
7A'
3G
7A
23
8A
3D
11
13
11A
14C

FIG. 6A

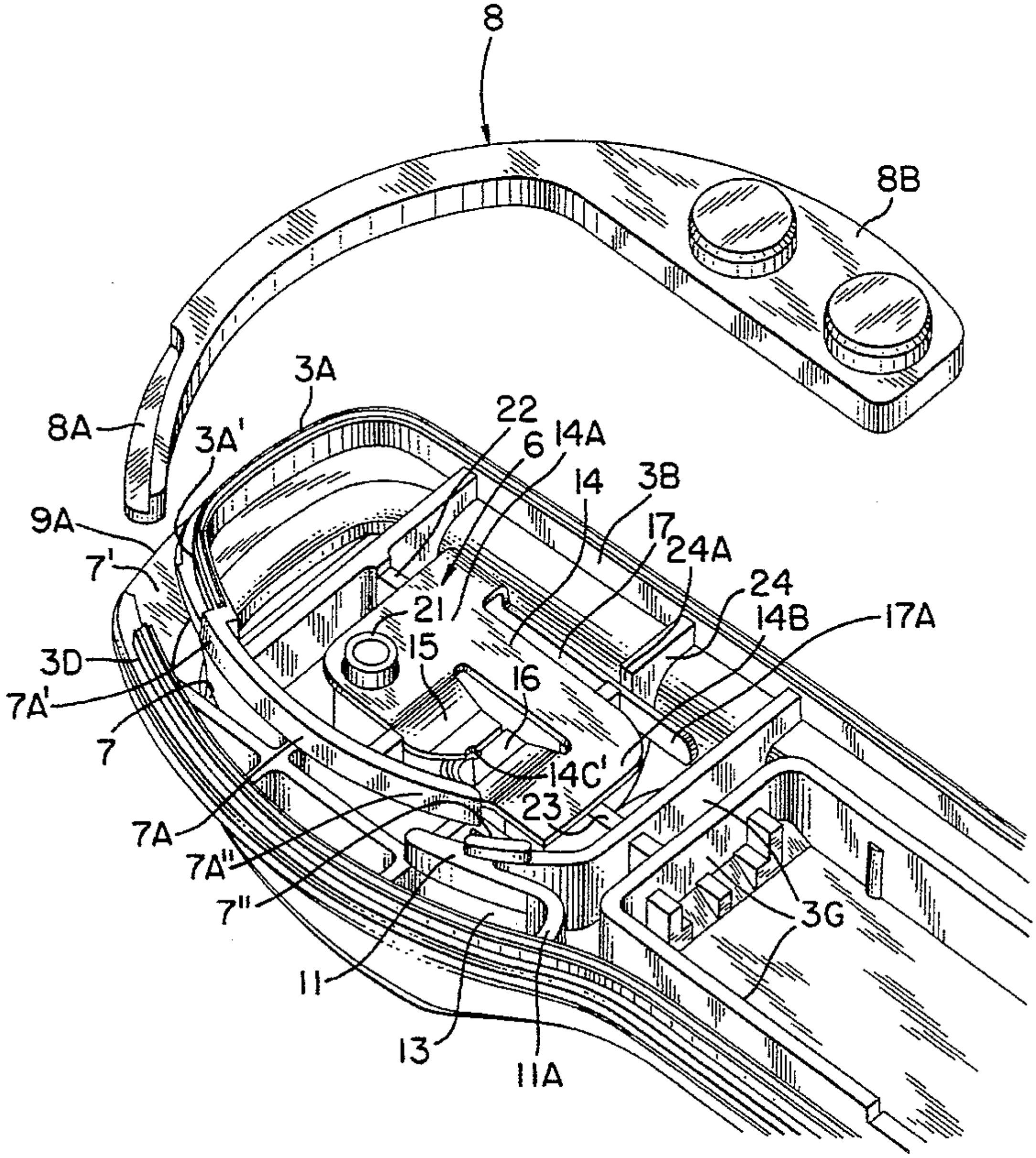

8
8B
3A
8A
3A'
22
6
14A
14
3B
9A
17
24A
7'
24
14B
17A
21
15
3D
16
7A'
7
14C'
23
7A
7A''
3G
7''
11
13
11A

FIG. 6B

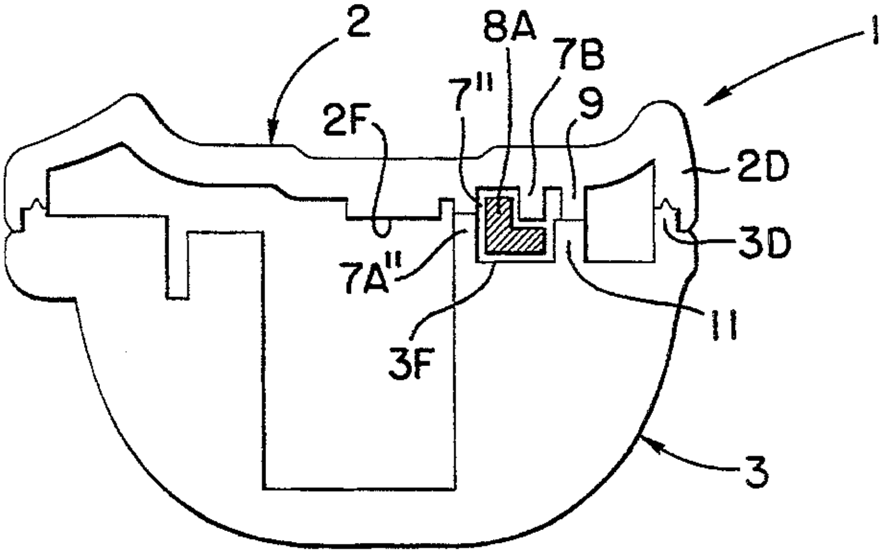


FIG. 7

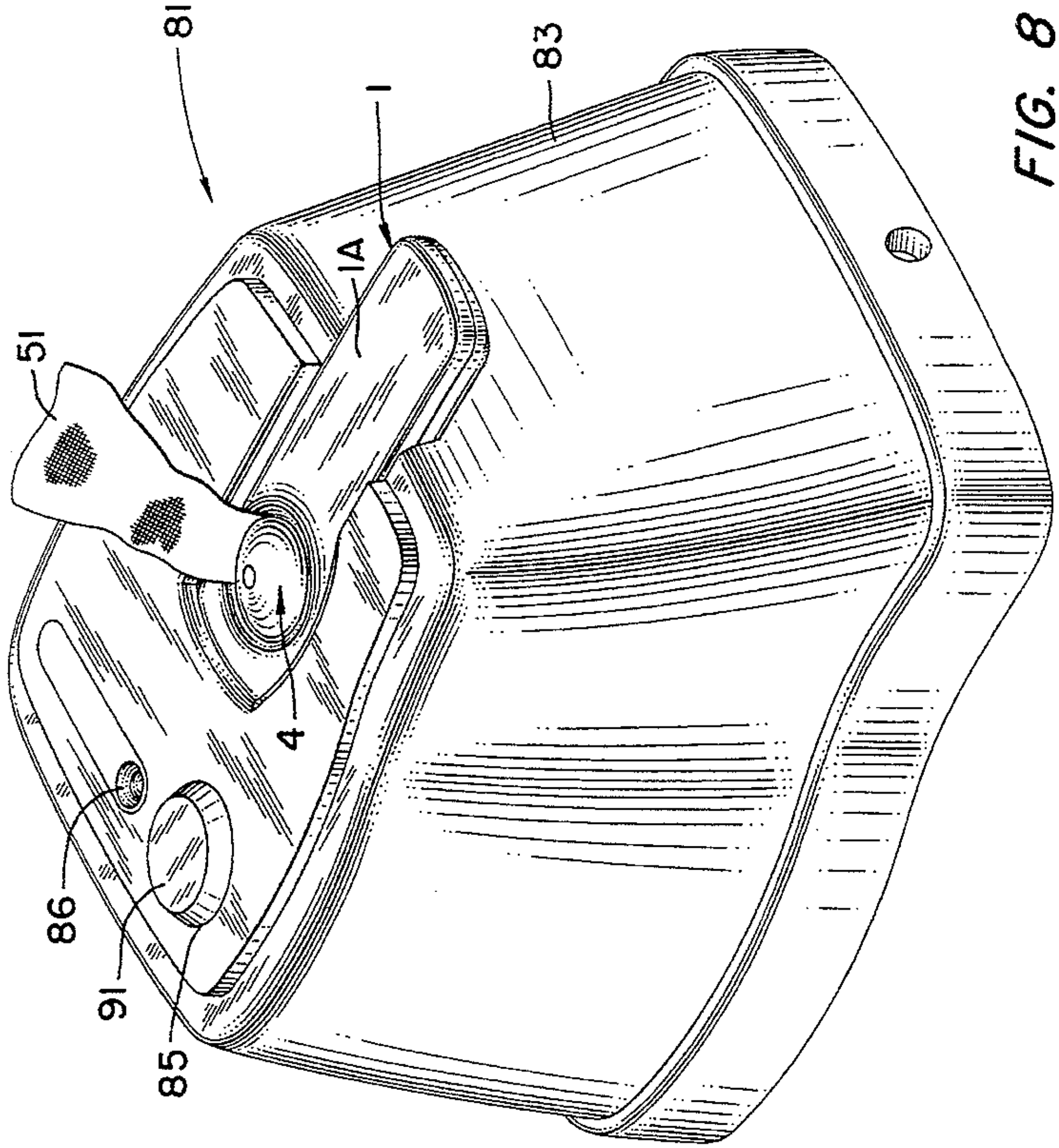


FIG. 8

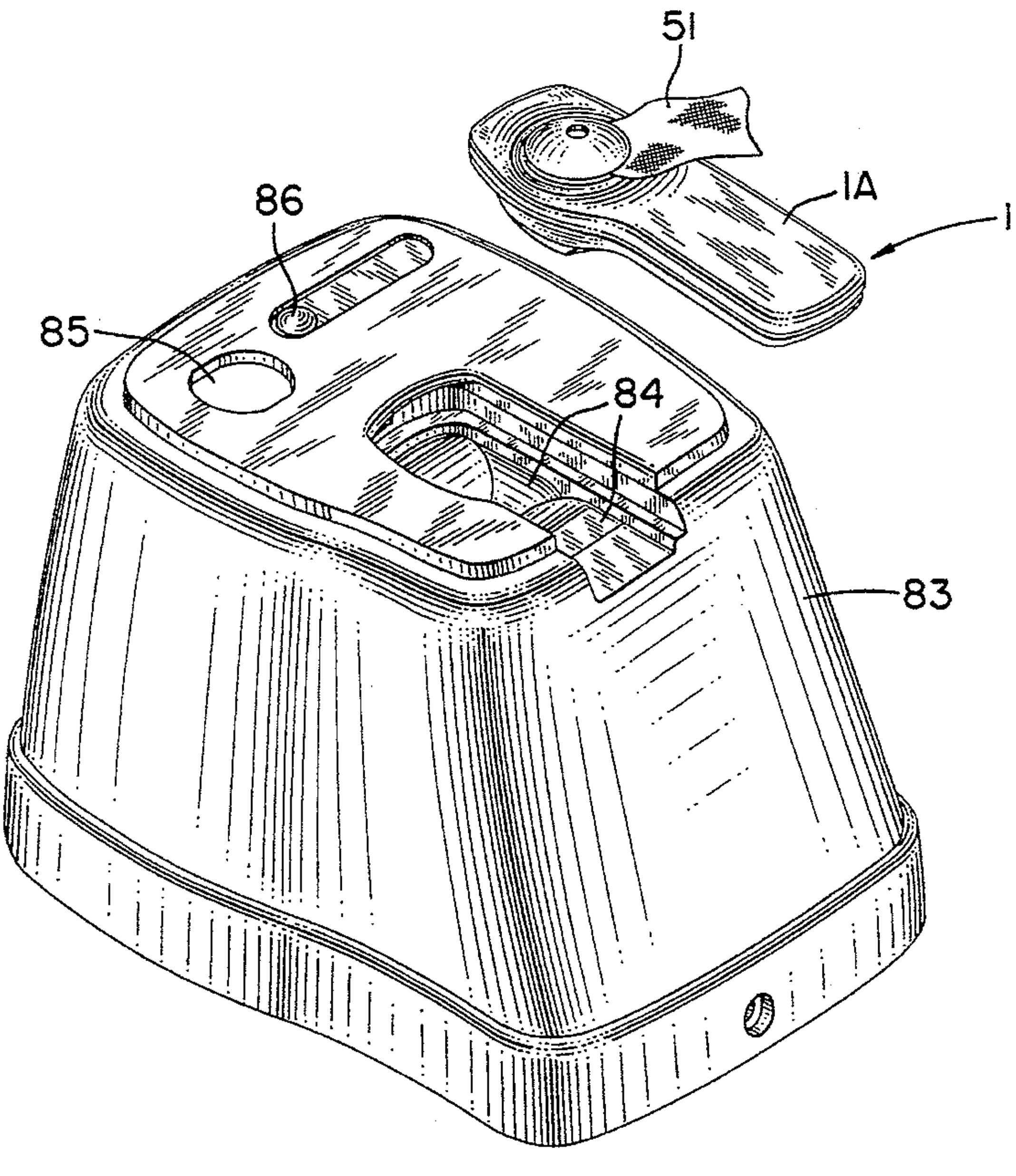
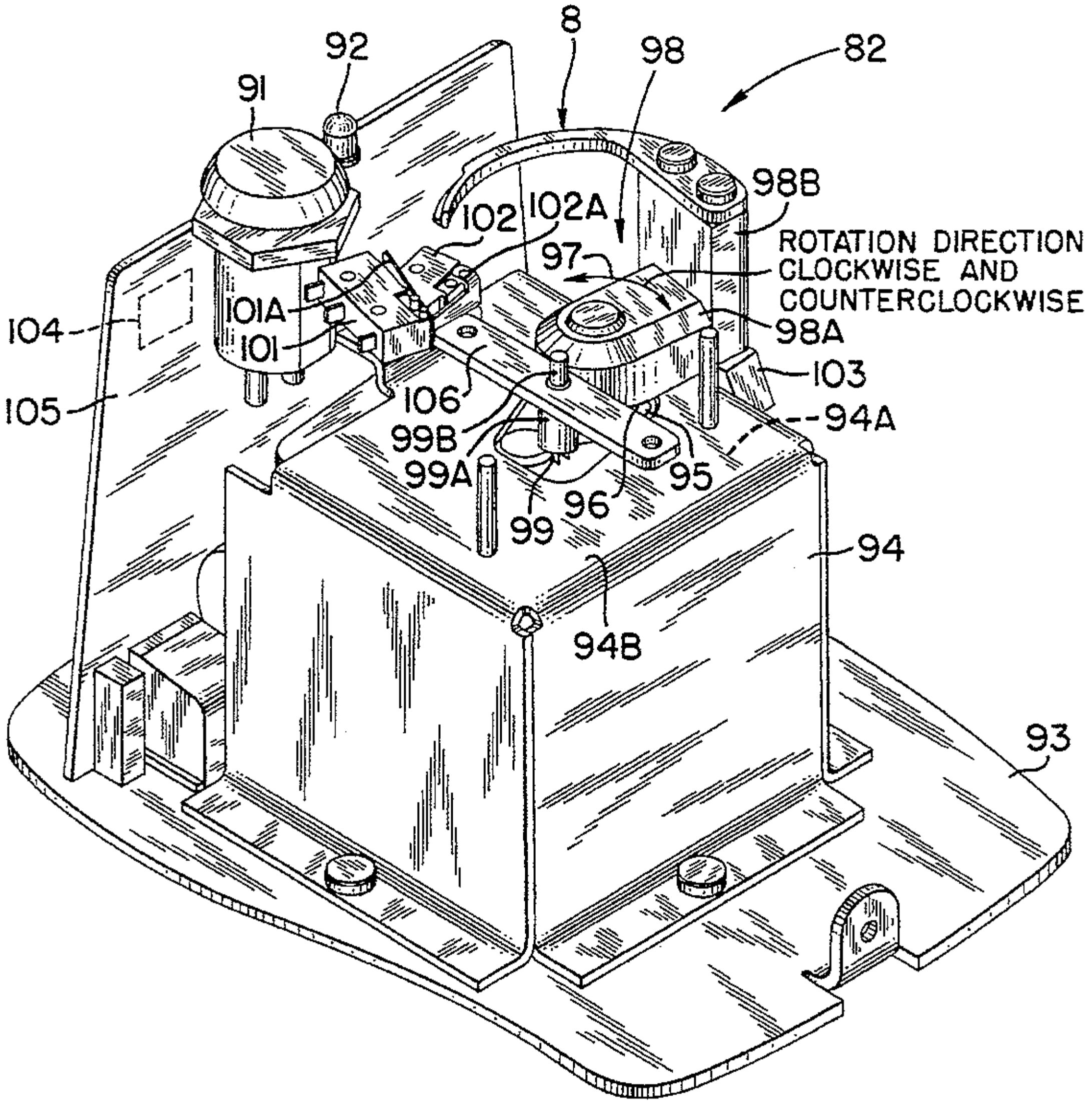


FIG. 9



8
92
98
82
91
98B
102
102A
ROTATION DIRECTION
CLOCKWISE AND
COUNTERCLOCKWISE
97
101A
104
101
98A
103
105
106
99B
94A
99A
95
96
99
94
94B
93

FIG. 10

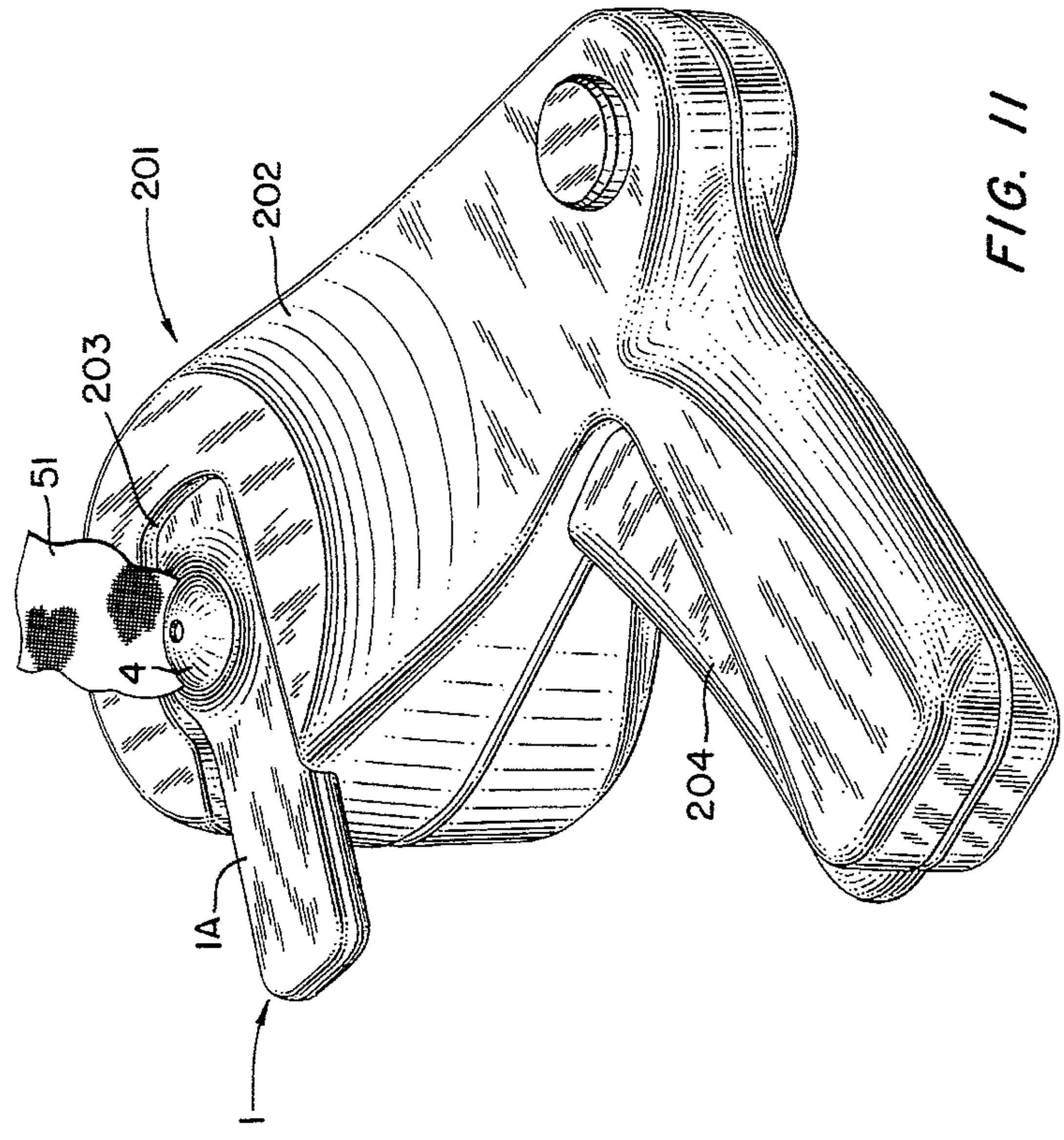


FIG. 11

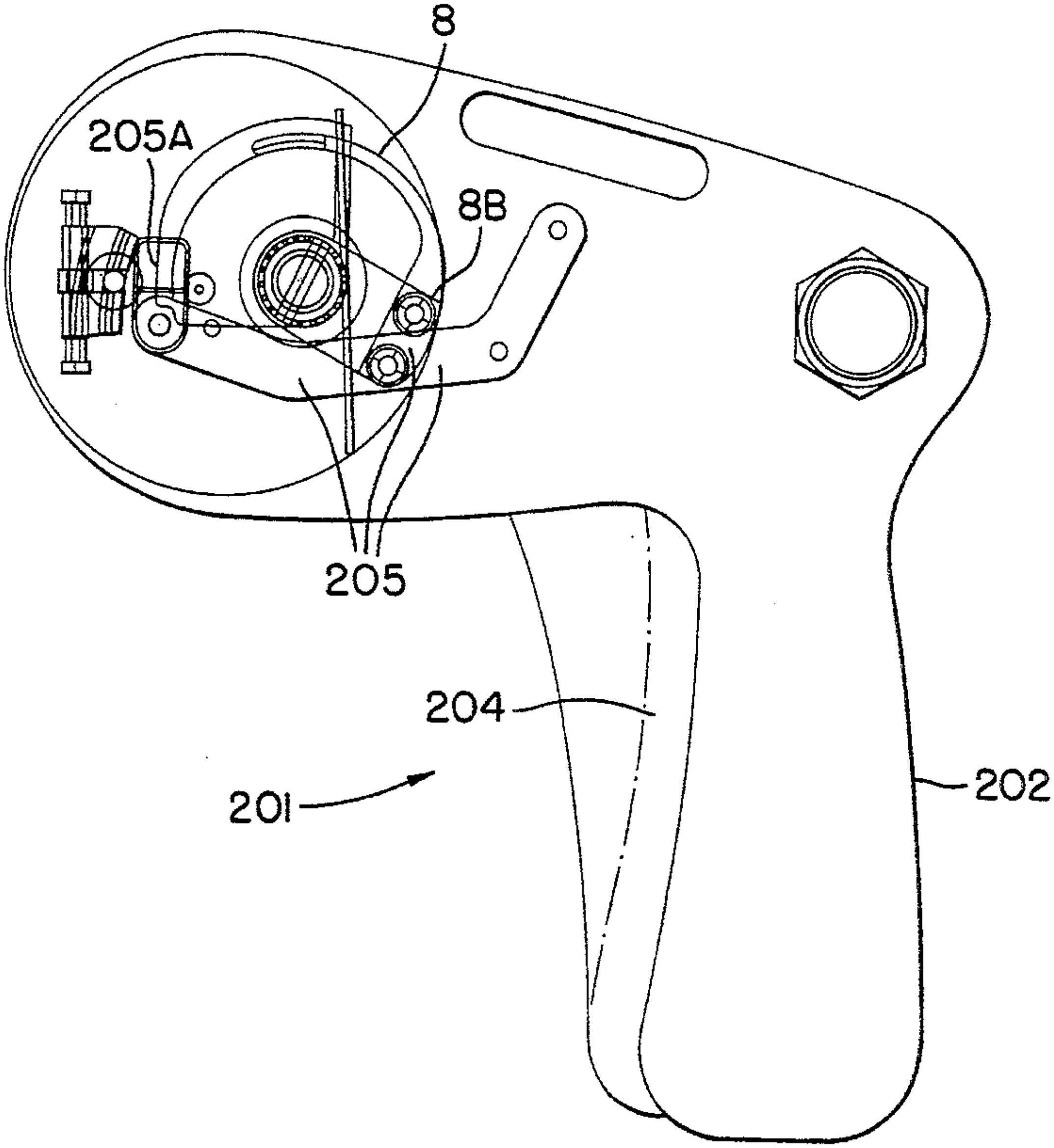


FIG. 12

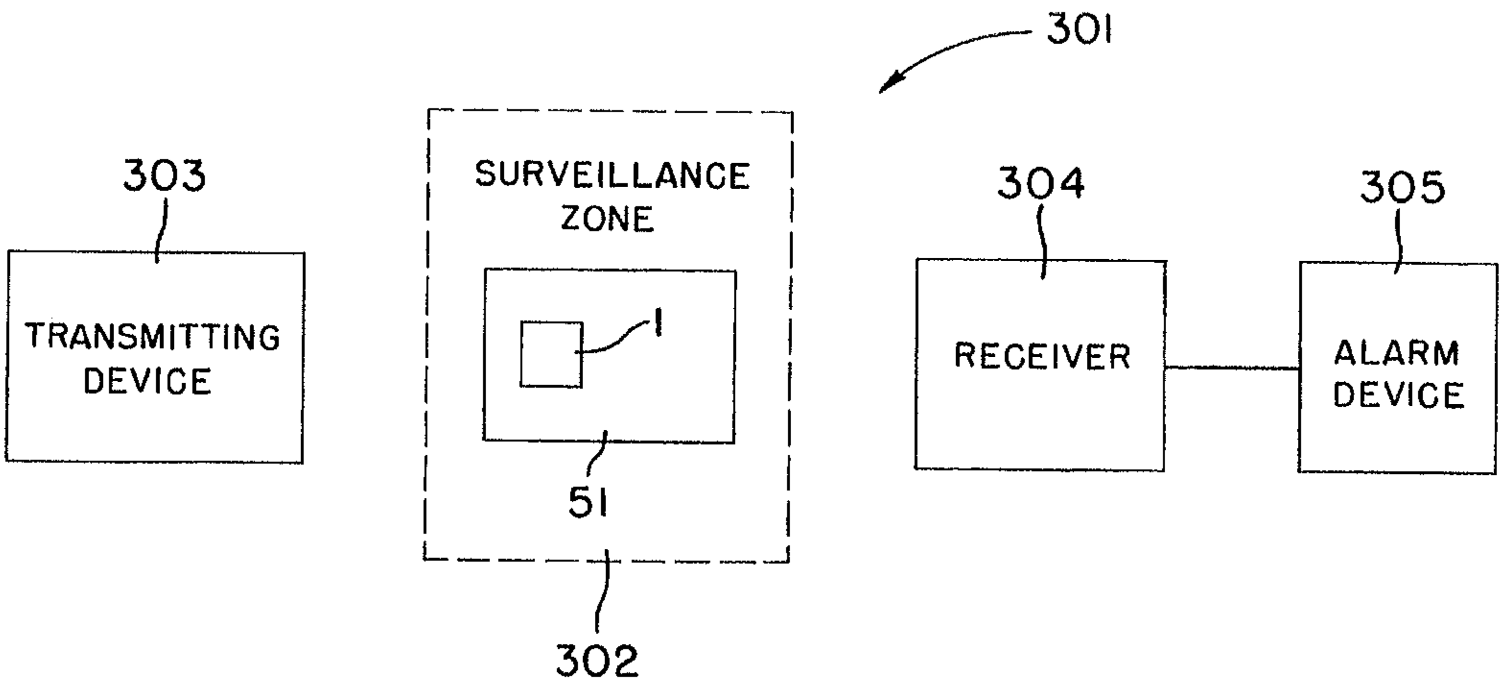

301
303
TRANSMITTING DEVICE
SURVEILLANCE ZONE
1
51
302
304
RECEIVER
305
ALARM DEVICE

FIG. 13

SECURITY TAG HAVING ARCUATE CHANNEL AND DETACHER APPARATUS FOR SAME

BACKGROUND OF THE INVENTION

This invention relates to security tags and associated detachers and, more particularly, to a security tag and an associated detacher for use in an electronic article surveillance (EAS) system.

Electronic article surveillance systems are well known in the art and are used for inventory control and to prevent theft and similar unauthorized removal of articles from a controlled area. Typically, in such systems a system transmitter and a system receiver are used to establish a surveillance zone which must be traversed by any articles being removed from the controlled area.

An EAS tag is affixed to each article and includes a marker or sensor adapted to interact with a signal being transmitted by the system transmitter into the surveillance zone. This interaction causes a further signal to be established in the surveillance zone which further signal is received by the system receiver. Accordingly, upon movement of a tagged article through the surveillance zone, a signal will be received by the system receiver, identifying the unauthorized presence of the tagged article in the zone.

Certain types of EAS tags have been designed to be reusable and, thus, include releasable attachment devices for affixing the tags to the articles. Such attachment devices are further designed to be releasable by authorized personnel only so that unauthorized removal of a tag from its article is avoided. To this end, many attachment devices are made releasable only through the use of an associated special tool or detaching mechanism.

An EAS tag employing an attachment device and an associated detacher is described in U.S. Pat. No. 3,942,829, entitled REUSABLE SECURITY TAG, issued to Humble, et al. on Mar. 9, 1976 and assigned to same assignee hereof. The EAS tag of the '829 patent includes a tag body and an attachment device in the form of a tack assembly. The tack assembly includes an enlarged head and a tack body having a pointed end which serves to pierce through an article and to be receivable in and clamped to the tag body. This secures the article and tag together.

In the tag of the '829 patent, the tack is clamped to the tag body using a spring clamp formed as a clutch lock with spreadable jaws. Once the article is pierced, the pointed tack end is received in the tag body and is secured between the jaws of the clutch lock. This locks the tack and the tag body forming the EAS tag to the article so that the tag and article cannot be readily separated from each other.

In order for authorized personnel to be able to release the tack from the clutch lock and, therefore, the tag from the article, the '829 patent utilizes a detacher mechanism which is adapted to grip the tag body and apply a bending force thereto. This force is sufficient to deform the clutch lock so that the jaws of the clutch lock are spread apart, thereby releasing the tack. The tack can then be removed from the tag body so that the article and tag become separated from one another.

To permit the bending of the tag body sufficiently to deform the clutch lock, the tag body of the '829 patent must be made of a flexible material. Typically, flexible plastic materials such as, for example, polypropylene, have been used. Such materials, however, are susceptible to being cut and damaged. This tends to be a disadvantage, since it increases the likelihood that the locking feature of the tag can be separated from the EAS sensor part of the tag or can be exposed and defeated.

Moreover, the tag body of the '829 patent must be relatively large in size in order to facilitate its flexing. This likewise tends to be a disadvantage, since use of large tags detracts from the aesthetic appearance of the articles to which the tags are attached.

Another type of EAS security device is known in which a variation of the spring clamp of the '829 patent has been incorporated into a so-called keeper for a compact disc. This type of device is disclosed in U.S. Pat. No. 5,031,756, entitled KEEPER FOR COMPACT DISC PACKAGE OR THE LIKE, issued to Buzzard, et al. on Jul. 16, 1991 and also assigned to same assignee hereof.

The keeper of the '756 patent comprises a rigid plastic frame. One side of the frame is provided with an enlarged section which houses a tack-like button assembly and a spring clamp as in the '829 patent. In this case, the spring clamp is used to lock the button assembly in a first position. In this position, the pointed end of the button assembly protrudes into the frame to pierce and hold to the frame a cardboard container containing a compact disc. As a result, unauthorized removal of the compact disc with the frame causes an EAS sensor also incorporated into the frame, to generate a detectable signal for alarming an EAS system.

In the keeper of the '756 patent, the enlarged section of the frame is provided with opposing linear slots which lead to the region between the jaws of the spring clamp. By inserting ramped linear fingers into these slots, the fingers are guided into this region, causing the jaws to flex outward. This releases the button enabling it to be withdrawn from the cardboard container. The container and its housed compact disc can then be separated from the frame.

While the keeper of the '756 patent utilizes a spring clamp of the '829 patent type in a rigid frame, it also has certain drawbacks. One drawback is that the linear slots leading to the spring clamp permit in-line viewing and access to the clamp. This increases the susceptibility of the clamp to defeat, since linear objects can be inserted into the slots in an attempt to open the jaws. Another drawback is that the fingers of the detacher are required to be of high precision, since they must be received in the region between the spring clamp jaws. This increases the cost and complexity of the detacher.

It is, therefore, an object of the present invention to provide an EAS tag which does not suffer from the above disadvantages.

It is a further object of the present invention to provide an EAS tag having a hard tag body and which is adapted to be releasable from an article in an easy and simple manner.

It is also an object of the present invention to provide an EAS tag as set forth in the previous objectives and which is further adapted to be more difficult to defeat.

It is yet a further object of the present invention to provide a detacher for use in detaching the EAS tags set forth in the previous objectives.

SUMMARY OF THE INVENTION

In accordance with the principles of the present invention, the above and other objectives are realized in an EAS tag of the above-described type in which the

tag is provided with a tag body and with an attaching means for attaching the tag body to an article. The attaching means includes a part which is receivable in the tag body and the tag body is provided with further means for releasably preventing withdrawal of the attaching means part.

Channel defining means within the tag body defines an arcuate channel. This channel leads to the preventing means and permits an arcuate probe to be guided to such means for releasing same. Release of the preventing means permits withdrawal of attaching means part thereby separating the attaching means and article from the tag body.

In the embodiment of the invention to be disclosed hereinafter, the attaching means comprises a tack having a head and a tack body, the latter being the part of attaching means receivable in the tag body through a first opening. The preventing means includes a receiving and clutching means which receives and clutches the tack body, thereby preventing withdrawal of the tack body from the tag body. A release part of the receiving and clutching means when engaged causes the receiving and clutching means to release, thereby allowing withdrawal of the tack body. A second opening in the tag body leads to the arcuate channel which, in turn, leads to the release part of the receiving and clutching means to allow the arcuate probe to engage same to effect the release.

In a further aspect of the invention, a unique spring clamp is utilized for the receiving and clutching means. This spring clamp includes a clamp body and jaws which extend from the plane of the clamp body. A first area of the clamp body on one side of the jaws is adapted to permit the clamp body to be mounted in the tag body, while a second area of the clamp body on the other side of the jaws is adapted to receive a torsional force in the plane of the clamp body. The jaws of the spring clamp are further adapted such that the in-plane torsional force on the second area of the clamp body enables opening of the jaws and release of the spring clamp.

In the embodiment of the spring clamp to be disclosed hereinbelow, the jaws are integral with the clamp body and comprise first and second sections which extend out of the plane of the spring clamp and then toward each other terminating in spaced edges which extend to a common edge of the spring clamp. The first and second areas of the spring clamp also extend to this common edge and laterally outward of the first and second sections, respectively. An aperture in the first area permits pivotal mounting of the spring clamp body and an elongated spring arm is attached to a further edge of the clamp body opposite the common edge. The spring arm returns the clamp body to its initial position after rotation or pivoting of the clamp body as a result of the in-plane torsional force.

In yet a further aspect of the present invention, a detacher mechanism is provided for detaching the EAS tag of the invention from an article. The detacher comprises an arcuate probe which is adapted to be received in the arcuate channel of the tag. Means is further provided for moving the arcuate probe so that it is received in and withdrawn from the channel. This moving means is adapted to rotate the probe, while support means supports the tag in proper relationship to the probe.

Hand actuated and power actuated/tag activated detacher embodiments are disclosed. The hand actuated detacher includes a hand actuatable button and a mechanical linkage linking the button and the probe driving means. The tag actuated detacher includes motor means for driving the probe, electronics for controlling the motor and sensors for detecting the position of the tag and probe.

BRIEF DESCRIPTION OP THE DRAWINGS

The above and other features and aspects of the present invention will become more apparent upon reading the following detailed description in conjunction with the accompanying drawings, in which:

FIG. 1 shows an EAS tag and associated detacher probe in accordance with the principles of the present invention;

FIG. 2 shows a cross-section of the EAS tag of FIG. 1 taken along the line A—A in FIG. 1;

FIG. 3 shows a view of the interior of the lower housing of the EAS tag of FIG. 1;

FIG. 4A shows a view of the interior of the upper housing of the EAS tag of FIG. 1;

FIG. 4B shows a view of the exterior of the upper housing of the EAS tag of FIG. 1;

FIG. 5 illustrates an exploded view of the spring clamp used in the EAS tag of FIG. 1;

FIGS. 6A and 6B show partial views of the interior of the lower housing of the EAS tag of FIG. 1 with the probe inserted in and withdrawn from the arcuate channel of the tag, respectively;

FIG. 7 is a cross section of the EAS tag of FIG. 1 taken along the line B—B in FIG. 1 with the probe inserted in the arcuate channel in the tag;

FIG. 8 shows a power actuated/tag activated detacher assembly for detaching the EAS tag of FIG. 1 from an article;

FIG. 9 shows the outer cover of the detacher assembly of FIG. 8;

FIG. 10 shows the detaching mechanism of the detacher assembly of FIG. 8.

FIG. 11 shows a hand actuated detacher assembly for detaching the EAS tag of FIG. 1 from an article;

FIG. 12 shows the detaching mechanism of the detacher assembly of FIG. 11; and

FIG. 13 shows an electronic article surveillance system for use in conjunction with the EAS tag of FIG. 1.

DETAILED DESCRIPTION

FIGS. 1–7 show various views of an EAS tag 1 in accordance with the principles of the present invention. As shown (see, FIG. 1), the tag 1 includes an upper housing 2 having side walls 2A, 2B, 2C and 2D which are joined by a top wall 2E. The tag 1 also includes a lower housing 3 having side walls 3A, 3B, 3C and 3D which are joined by a bottom wall 3E. The upper and lower housings 2 and 3 are joined or mated along corresponding or associated side wall pairs (2A, 3A), (2B, 3B), (2C, 3C) and (2D, 3D) to form a closed tag body 1A.

The housings 2 and 3 are preferably made of a hard or rigid material. A usable rigid or hard material might be a hard plastic such as, for example, an injection molded ABS plastic. If a plastic is used, the mating side walls of the housings can be joined by an ultrasonic weld 1B or like joining mechanism.

The tag 1 further includes a tack assembly 4 shown as having an enlarged tack head 4A and an elongated tack body 4B provided with slots or grooves 4C and a pointed forward end 4D (see, FIGS. 1, 2 and 6A). The

tack assembly **4** is used to attach the tag body **1A** to an article **51** which is to be protected by the EAS tag **1**.

In order to sense the tag **1** and, therefore, detect the presence of the tag and the attached article **51**, the inner surfaces **2F** and **3F** of the walls **2E** and **3E** of the housings **2** and **3** are provided with frame members **2G** and **3G** which together define an interior cavity **1C** for receiving an EAS sensor **5** (see, FIGS. **2**, **3** and **4A**). The EAS sensor **5** generates detectable signals and can be an acoustically resonant magnetic sensor as disclosed in U.S. Pat. Nos. 4,510,489 and 4,510,490. Possible other magnetic EAS sensors usable for the sensor **5** might be those disclosed in U.S. Pat. Nos. 4,686,516 and 4,797,658 and possible RF EAS sensors might be those disclosed in U.S. Pat. Nos. 4,429,302 and 4,356,477. The teachings of these patents are incorporated herein by reference.

As above-noted, the article **51** is joined to the tag body **1A** by the tack assembly **4**. This is accomplished by inserting the tack body **4B** into an opening **2H** in the wall **2E** of the upper housing **2**. When the tack body **4B** is fully inserted, the pointed end **4D** of the tack is received in an upstanding cavity or collar **3H** extending from the inner surface **3F** of the lower housing wall **3E**. The tack head **4A**, in turn, seats in a recessed area **2I** in the upper surface **2J** of the wall **2E**. The article **51** is thus held between the tack head **4A** and the latter wall.

Means **6** to be discussed in greater detail below is provide within the tag body **1A** for releasably preventing the tack body from being withdrawn from the tag body. The tack assembly **4B** the article **51** thus become releasably locked to the EAS tag by the means **6**.

In accordance with the principles of the present invention, the EAS tag **1** is further adapted so that access to the means **6** for releasing same is made difficult for other than authorized personnel. To this end, the tag body **1A** is configured so that access to the means **6** is through an arcuate channel **7** (see FIGS **1**, **3**, **4A**, **4B**, **6A** and **6B**) defined by one or more inner walls and by parts of the side walls and upper and lower walls of the tag body **1A**. With this configuration, a special arcuate probe **8** is needed to reach and release the means **6** and, thus, detach the tack assembly **4** and the article from the tag body **1A**.

As shown, the arcuate channel **7** is defined by a curved inner wall **7A**. This wall extends upward from the inner surface **3F** of the bottom housing **3** to abut the inner surface **2F** of the upper housing **2**. The wall **7A** is further spaced from the side wall **3D** of the bottom housing **3** and its outward end **7A'** terminates at an inward curved part **3A'** of the side wall **3A**. The inward curved part **3A'** of the wall **3A** results in a space or slot **9A** between the side walls **3A** and **3D** of the lower housing **3**.

The slot **9A** cooperates with a similar slot **9B** between the sides wall **2A** and **2D** of the upper housing **2** to define a second opening **9** for providing entry or access into the outward end **7'** of the channel **7**. At this entry point, the side wall **2A** also curves inwardly at a part **2A'**, the latter part **2A'** mating with the curved side wall part **3A'** of the side wall **3** of the lower housing **3**.

The channel **7** is further defined by a second curved wall **7B** (see, FIGS. **4A** and **7**) extending downwardly from the inner surface **2F** of the upper housing **2**. The wall **7B** is situated outward of the inner end **7A"** of the curved wall **7A** and extends beyond this end to the frame member **2G**.

The presence of the wall **7B** changes or alters the configuration of the channel **7** at its inner end **7"** which end lies adjacent the means **6** (see, FIG. **6B**). This change or alteration in configuration defines a keyway for the channel **7** which must b accommodated by the probe **8** to pass through the channel and gain access to the means **6**.

In the case illustrated, the wall **7B** changes the channel cross section from substantially rectangular to substantially L-shaped. This is illustrated in the cross section of FIG. **7** which has been taken along the line B—B in FIG. **1** so that the cross section of the channel end **7"** is made visible.

FIGS. **6A** and **6B** are enlarged views of the section of the lower housing **3** containing the means **6** and the arcuate channel **7**. In FIG. **6A**, the arcuate probe **8** is shown as received in and guided by the channel **7** to the means **6** for the purpose of releasing same. As can be seen, the forward end **8A** of the probe **8** is recessed so as to be L-shaped and, thus, fit within the L-shaped keyway defined by inner end **7"** of the channel. In FIG. **6B**, the probe **8** is shown as withdrawn from the channel.

Adjacent the inner end **7"** of the channel **7**, the lower and upper housings **2** and **3** are provided with further curved walls **9** and **11** which terminate in wall sections **9A** and **11A** abutting the end walls **2D** and **3D**. The walls **9** and **11** are outward of the channel **7** and, with the end walls **2D** and **3D**, define a trap area **13** which prevents access to the means **6**. This area provides a safety measure for blocking unauthorized objects introduced into the channel **7** of the tag body **1A** in an attempt reach the means **6**.

As above-noted, the means **6** is adapted to releasably prevent the tack body **4B** from being withdrawn from the tag body **1A**. More particularly, in further accord with the invention, the means **6** is specifically adapted to accommodate release of the tack body **4B** via the arcuate probe **8** moving in the arcuate channel **7**. The means **6** is shown in detail in FIGS. **6A** and **6B** and in an exploded view in FIG. **5**.

As shown, the means **6** is in the form of a spring clamp having a clamp body **14** and jaws **15** and **16**. The clamp body includes a mounting part **14A** extending laterally of the jaw **15** and a release part **14B** extending laterally of the jaw **16**. The mounting part **14A** includes a mounting aperture **14A'**.

Each of the jaws **15**, **16** extends outwardly of the plane of the clamp body **14** and then inwardly toward the other jaw. The jaws **15**, **16**, furthermore, terminate in facing edges **15A** and **16A**. These edges extend from a common edge **14C** of the clamp body **14** inwardly toward each other, then curve outwardly away from each other to define an aperture **14C'** (typically, circular or elliptical) for receiving the tack body **4B**. The edges **15A** and **16A** then continue in aligned fashion and end in an elongated, lateral slot **14D** in the clamp body **14**. The latter slot lies inward of a further clamp body edge **14E** which opposes the clamp body edge **14C**.

A further laterally extending elongated spring sleeve or arm **17** is attached by a joint area **18** to the side **14E'** of the edge **14E** bordering the mounting part **14A**. The sleeve **17** extends along the length of the edge **14E** and is also out of the plane of the clamp body.

For mounting and supporting the spring clamp **14**, the lower housing **3** of the tag body **1A** includes a hollow circular mount **21** with a lip **21A** and support walls **22**, **23** and **24** (see, FIGS. **2**, **3**, **6A** and **6B**). The clamp is mounted, via the aperture **14A'** of the mounting part

14, on the mount **21** with the area of mounting part adjoining the aperture **14A'** supported on the lip **21A**. A circular wall **25** of the upper housing **3** and a central cylindrical stud **26** of this housing (see, FIGS. **2** and **4A**) maintain the mounting part **14A** in its mounted position, while allowing the mounting part to be rotated. The spring clamp **14** is thus able to pivot about the mounting part as will be described more fully below.

The back end **14A"** of the mounting part **14A** and the lateral part of the clamp connecting the mounting part **14A** and the release part **14B** are supported on the support walls **22** and **24**, while the release part is carried by the wall **23**. The spring sleeve **17** rests with one end **17A** in a slot **24A** in the support wall **24**.

When the pointed end **4D** of the tack body **4B** is introduced in the downward direction through the opening **2H** in the upper housing **2**, the part **2K** of the upper housing, which part is shaped to fit within the hollow of the spring clamp body **14** above the jaws **15**, **16** and carries the opening **2H**, directs the tack body to the aperture **14C'** defined by the facing edges **15A**, **16A** of the jaws. This causes the jaws to spread or open and allow the tack body **4B** to pass through the jaws.

When the downward tack travel is stopped at a desired slot **4C**, i.e., a slot which provides a tight fit of the tack head **4A** and article **51** to the wall **2E** of upper housing **2**, the jaws **15**, **16** retract and clutch the tack body **4B**. In this position, the jaws **15**, **16** prevent upward movement of the tack **4**. The tack **4** and article **51** thus become locked to the tag body **1A**.

In order to release the tack **4** from the tag body **1A**, the arcuate probe **8** is now introduced into the opening of the tag body **1A** via rotation of the probe about its rearward end **8B**. This causes the probe to be moved in and guided by the channel **7** until the L-shaped forward end **8A** of the probe reaches and passes into the L-shaped inner end **7"** of the channel **7**. This brings the probe end **8A** to the part of the common edge **14C** bordering the release part **14B** of the clamp body **14**.

Continued rotational movement of the probe **8** then causes a on the release part **14B**. This force, in turn, causes the clamp body **14** to rotate about the support area **14A** on the mount **21**. The jaws **15**, **16** are thus enabled to spread apart or open due to the force of the tack body **4B**, which is held stationary by the collar **3H**, acting on the walls of the aperture **14C'**. The aperture **14C'** thus expands, releasing the tack body **4B** from the grip or clutch of the jaws. The tack **4** can now be moved in the upward direction past the jaws, via an upward force on the tack head **4A**, thereby withdrawing and separating the tack body **4B** from the tag body **1A** and the article **51** from the tag **1**.

During rotation of the spring clamp body **14** as a result of the in-plane force exerted by the probe **8**, the spring arm **17** at the joint **18** is compressed. After the tack **1** is separated from the tag body **1A**, the probe **8** is rotated in the reverse direction. This reverse rotation disengages the probe from the release part **14A** of the spring clamp **14** as the probe **8** is withdrawn from the channel **7**. The force on the spring clamp **14** is thus removed and the spring arm **17** expands. This causes the spring clamp **14** to rotate in the opposite direction about the support area **14A**. The spring clamp **14** is thereby brought back to its original position awaiting reentry of the tack body **4B** for again attaching an article to the tag **1**.

FIGS. **8–10** and **11–12** show two embodiments of detaching assemblies which incorporate the arcuate detaching probe **8**. Each of these assemblies can be used to rotate the probe as above-described to detach the tack **4** from the tag **1**.

The detaching assembly **81** of FIGS. **8–10** is a power actuated/tag activated assembly and includes a detaching mechanism **82** (see, FIG. **10**) which is covered by a removable detacher cover **83**. As shown in FIGS. **8** and **9**, the detacher cover **83** includes a nesting or cradle area **84** for receiving the tag body **1A** of the tag **1**. The cover **83** also includes an ON/OFF switch aperture **85** sized to accommodate an ON/OFF switch **91** of the detaching mechanism **82**. A further aperture **86** of the cover **83** receives a light emitting diode (LED) **92** which indicates the on/off status of the detaching mechanism.

As shown in FIG. **10**, the detaching mechanism **82** includes a frame or bottom plate **93** to which is affixed a motor cover **94** having in its upper surface **94B** an opening **95**. The motor cover **94** houses a motor **94A** supported on the plate **93**. The motor **94A** drives an upstanding shaft **96** which projects out of the opening **95** and is rotatable in either a clockwise or counterclockwise direction as desired (indicated by arrows **97**).

A rotatable member **98** has a base **98A** which is fixedly attached to an upstanding section **98B**. The base **98A** is coupled to the shaft **96** and it and the upstanding section **98B** rotate with the rotation of the shaft. The upstanding section **98B** carries the rearward end **8B** of the arcuate probe **8** and rotation of the section **98B** causes rotation of the probe **8**, as above-described.

In order to effect automatic rotation of the probe **8** from an initial position (shown in FIG. **10**) to a detachment position (shown in FIG. **6A**) and then back to its initial position, the detaching mechanism **82** is additionally provided with first and second activator switches **99** and **101**, a reverse switch **102** and a home switch **103**. These switches provide signals over lines (not shown) to control electronics **104** mounted on a PC board **105** attached to the base **93**. The control electronics **104**, in turn, provide drive signals to the motor **94A** for driving same to realize movement of the probe arm **8**, as above-described.

As shown, the activator switch **99** is mounted on the upper surface **94B** of the of the motor cover **94** and includes a body **99A** which supports a platform element **106**. A spring biased upstanding plunger **99B** of the switch **99** extends from the body **98A** through the platform element **106** and movement of the plunger **99B** downward causes activation of the switch **99**. The second activator switch **101** is also mounted to the motor cover **94**, but at the forward end of the platform element **106**. The switch **101** includes an outwardly extending reed element **101A** which when engaged causes activation of the switch.

When the tag **1** is properly mounted in the cradle area **84** of the cover **83**, both the plunger **99B** of the switch **99** and the reed element **101A** of the switch **101** become engaged. This results in simultaneous activation of both the switches **99** and **101**, causing simultaneous activation signals to be present at the control electronics **104**. The control electronics recognizes this activated condition as signifying that a tag **1** is properly situated in the detacher assembly. It thereupon signals the motor to counterclockwise rotate to move the probe **8** counterclockwise from its initial position into the tag body.

The reverse switch **102** is affixed to the motor cover **94** and has a reed element **102A** extending toward the base **98A** and positioned to be engaged by the base

when the counterclockwise moving probe **8** reaches its detachment position, i.e., its position as shown in FIG. 6A. Activation of the reverse switch by engagement of the reed element **102A** causes a further signal to be received by the control electronics **104**, indicating that the probe **8** has effected detachment and that the motor rotation should be reversed to withdraw the probe from the tag body. The motor drive signal is changed accordingly and the motor reversed. This causes the base **98A** and section **98B** to be clockwise rotated, likewise clockwise rotating the probe **8** bringing it out of the tag and back to its initial or starting position.

The home switch **103** is affixed to the motor cover **94** adjacent the upstanding section **98B**. As the base **98A** and upstanding section **98B** are clockwise rotated, a reed element (not shown) on the switch **103** is engaged by the base **98A** as the probe **8** returns to its initial position. This results in the home switch **103** signaling the control electronics **104** that the probe **8** has reached this position. The control electronics **104** then adjusts the drive signals to the motor so that the motor rotation stops and the probe **8** is brought to rest at the initial position.

FIGS. **11** and **12** show a second detaching assembly **201** usable to detach the tag **1** from the article **51**. In this case, the detacher is hand actuated and includes an outer housing **202** having a nesting area **203** for supporting the tag **1**. A trigger **204** is carried by the housing **201** for actuating the detacher and releasing the tag **1** from the article **51**.

As shown in FIG. **12**, the detaching assembly **201** includes an internal linkage mechanism **205** which is coupled to the trigger **204**. The linkage mechanism **205** carries the arcuate probe **8** via its base **8B** and is adapted to rotate the probe counterclockwise to a detach position **205A** when the trigger **204** is actuated. In this position, the probe **8** has entered the tag body, traversed the channel **7** and detached the pin **4** as shown in FIG. 6A.

After detachment has occurred, the trigger **204** is released. The linkage mechanism **205** then rotates the probe **8** clockwise, withdrawing it from the tag body and returning the probe to its initial position as shown in FIG. **12**.

FIG. **13** shows an EAS system **301** used to detect or sense the tag **1** when passing through a surveillance zone **302**. An interrogation signal is transmitted into the zone **302** via a transmitting device **303**. A signal resulting from interaction of the sensor **5** in the tag **1** with the transmitted signal is received at a receiver **304** which communicates with a detection and alarm device **305**. The latter detects the received signal and generates an alarm indicating the presence of the tag **1** and the article **51** in the surveillance zone **302**.

The particular configurations used for the devices **303**, **304** and **305** in the system **301** will depend on the particular nature of the sensor. For the types of sensors disclosed in the above-mentioned patents, devices of the types also disclosed in these patents can be used.

It should be noted that the spring clamp **14** of the tag **1** can be constructed of spring sheet metal. The probe **8**, in turn, can be constructed of hardened tool steel.

In all cases it is understood that the above-described arrangements are merely illustrative of the many possible specific embodiments which represent applications of the present invention. Numerous and varied other arrangements can be readily devised in accordance with the principles, of the present invention without departing from the spirit and scope of the invention. Thus, for example, the spring clamp release means **6** shown in FIG. **5** might be used with EAS tags of a construction which differ in one or more respects from that of the EAS tag **1** and which need not include an arcuate channel or be responsive to an arcuate detaching probe.

What we claim is:

1. An EAS tag comprising:
a tag body;
means for attaching said tag body to an article, said attaching means having a part which is received in said tag body;
means within said tag body for releasably preventing said part of said attaching means from being withdrawn from said tag body;
means within said tag body defining an arcuate channel leading from the exterior of said tag body to said preventing means, said arcuate channel being adapted to receive and guide an arcuate probe to said preventing means for releasing said preventing means from preventing said part of said attaching means from being withdrawn from said tag body;
and an detectable EAS sensor.

2. An EAS tag in accordance with claim **1** wherein:
said tag body has first and second openings leading into the interior of said tag body;
said attaching means includes a tack assembly having a tack head and an elongated tack body, said tack body being received in said first opening of said tag body and forming the part of the attaching means received in the tag body;
said preventing means includes means within the tag body for releasably receiving and clutching the tack body when the tack body is introduced into said tag body through said first opening, said receiving and clutching means upon receiving and clutching said tack body preventing withdrawal of said tack body from said tag body and including a release part which is adapted to be engaged by said arcuate probe to cause said receiving and clutching means to release clutching said tack body to permit said tack body to be withdrawn from said tag body;
and said arcuate channel leads from said second opening in said tag body to said release part of said receiving and clutching means, whereby said arcuate probe when introduced into said arcuate channel is brought into engagement with said release part of said receiving and clutching means to cause said receiving and clutching means to release clutching said tack body to allow withdrawal of said tack body from said tag body.

3. An EAS tag in accordance with claim **2** wherein:
said arcuate channel has a first predetermined configuration over a first length of said arcuate channel leading from said second opening and a second predetermined configuration over a second length of said arcuate channel terminating adjacent said release part of said receiving and clutching means.

4. An EAS tag in accordance with claim **3** wherein:
said first predetermined configuration is substantially of rectangular cross section;
and said second predetermined configuration is substantially of L-shaped cross section.

5. An EAS tag in accordance with claim **2** further comprising:
further means within said tag body defining a further channel adjacent to and outward of said arcuate channel, said further channel extending from adjacent to said release part of said receiving and

clutching means and inhibiting access to said release part of said receiving and clutching means.

6. An EAS tag in accordance with claim **5** wherein: said arcuate channel defining means and said further channel defining means each are formed by one or more walls interior of said tag body.

7. An EAS tag in accordance with claim **2** wherein: said tag body comprises: first and second elongated housings, each of said first and second elongated housings including first, second, third and fourth side walls and a further wall joining said first, second, third and fourth side walls, said first, second, third and fourth side walls of said first elongated housing mating with said first, second, third and fourth side walls of said second elongated housing, respectively, and said first opening extending from an outer surface of and through said further wall of said first elongated housing and said second opening extending from outer surfaces of mating side walls of said first and second elongated housings.

8. An EAS tag in accordance with claim **7** wherein: the outer surface of said further wall of said first elongated housing in the area of said first opening is recessed;

and said tack head seats in said recessed area when said tack body is received and clutched by said receiving and clutching means.

9. An EAS tag in accordance with claim **8** wherein: said tack body has a pointed forward end which passes through said receiving and clutching means when said tack body is clutched by said receiving and clutching means;

and an inner surface of said further wall of said second elongated housing has an aperture for receiving said pointed forward end of said tack body.

10. An EAS tag in accordance with claim **7** further comprising:

a mounting means attached to an inner surface of said further wall of said second elongated housing for mounting said receiving and clutching means such that said receiving and clutching means receives said tack body passing into said first opening and through said further wall of said first elongated housing and such that said receiving and clutching means upon engagement of said release part of said receiving and clutching means by said arcuate probe is rotated from a first position.

11. An EAS tag in accordance with claim **10** further comprising:

means for returning said receiving and clutching means to said first position upon disengagement of said arcuate probe from said receiving and clutching means.

12. An EAS tag in accordance with claim **10** wherein: said receiving and clutching means is rotationally mounted to said mounting means at a mounting part of said receiving and clutching means, said mounting part being off-set laterally from said release part.

13. An EAS tag in accordance with claim **12** wherein: said receiving and clutching means comprises: a spring clamp having a clamp body having first and second parts; and jaws comprising first and second jaw sections attached to said first and second parts, respectively, of said clamp body, said first part of said clamp body forming said mounting part of said receiving and clutching means and said second part of said clamp body forming said release part of said receiving and clutching means, said spring clamp being mounted at said first part so that when said tack body passes into said first opening and through said further wall of said first elongated housing in a first direction said tack body is received in and causes said first and second jaw sections of said jaws of said spring clamp to open, said first and second jaw sections of said jaws of said spring clamp gripping said tack body and preventing said tack body from being withdrawn from said jaws when said tack body is moved in a second direction opposite said first direction, said spring clamp being further mounted at said first part of said clamp body so that said clamp body pivots about said first part and said second part of said clamp body being adapted to receive a torsional force acting on said second part of said clamp body when said second part of said clamp body is engaged by said arcuate probe to cause said clamp body to pivot about said first part of said clamp body, said first and second jaw sections of said jaws of said spring clamp being configured such that said rotating of said clamp body about said first part of said clamp body caused by said torsional force acts to cause said first and second jaw sections of said jaws to open so as to release said tack body and permit withdrawal of said tack body from said first and second jaw sections of said jaws and said tag body in said second direction.

14. An EAS tag in accordance with claim **13** further comprising:

a spring means affixed to said spring clamp;

and an abutment affixed to said inner surface of said second elongated housing, said abutment being in engagement with said spring means.

15. An EAS tag in accordance with claim **13** further comprising:

a first curved inner wall attached to said inner surface of said second elongated housing and extending from adjacent said second opening past said first part of said clamp body to adjacent said second part of said clamp body, said first curved inner wall forming a part of said arcuate channel defining means.

16. An EAS tag in accordance with claim **15** further comprising:

a second curved inner wall attached to said inner surface of said first elongated housing, said second curved inner wall being displaced outward from said first curved inner wall and extending along a part of said first curved inner wall to adjacent said second part of said clamp.

17. An EAS tag in accordance with claim **13** wherein: said first and second law sections of said jaws are integrally formed with said first and second parts of said clamp body and terminate in spaced facing edges, said spaced facing edges of said first and second jaw sections extending from a common first edge of said clamp body.

18. An EAS tag in accordance with claim **17** wherein: said spaced facing edges of said first and second jaw sections extend from said common first edge of said clamp body inwardly toward each other, then curve to define an aperture for receiving said tack body and then terminate inwardly of a second edge of said clamp body.

19. An EAS tag in accordance with claim **18** wherein:

said first part of said clamp body extends to said common first edge and outward of said first section;

and said second part of said clamp body extends to said common first edge and outward of said second jaw section.

20. An EAS tag in accordance with claim 19 wherein:

said first part includes an aperture by which said clamp body is mounted.

21. An EAS tag in accordance with claim 20 further comprising:

a spring arm extending along the length of said second edge of said clamp body; and a curved joint joining said spring arm to an end of said second edge of said clamp body adjacent said first part of said clamp body.

22. An EAS tag in accordance with claim 2 wherein:

said tag body is formed of a hard plastic.

23. An EAS tag in accordance with claim 22 wherein:

said hard plastic is an injection molded ABS plastic.

24. An EAS tag in accordance with claim 2 wherein:

said arcuate channel defining means is formed by one or more inner walls of said tag body.

25. An EAS tag in accordance with claim 1 wherein:

said tag body is formed of a hard plastic.

26. An EAS tag in accordance with claim 25 wherein:

said hard plastic is an injection molded ABS plastic.

27. A spring clamp for use in releasably clamping an EAS article attaching means to an EAS tag body comprising:

a clamp body having first and second parts;

jaws comprising first and second jaw sections attached to said first and second parts, respectively, of said clamp body;

said first part of said clamp body being adapted to mount said clamp body to an EAS tag body so that said clamp body pivots about said first part of said clamp body;

said second part of said clamp body being adapted to receive a torsional force acting on said second part of said clamp body to cause said clamp body to pivot about said first part of said clamp body;

and said first and second jaw sections of said jaws being configured such that said pivoting of said clamp body about said first part of said clamp body caused by said torsional force acts to cause said first and second jaw sections of said jaws to open from a closed position, whereby when said clamp body is mounted to said EAS tag body and said first and second jaw sections of said jaws are in said closed position and gripping an EAS article attaching means, thereby clamping said EAS tag body to said EAS article attaching means, said opening of said first and second jaw sections from said closed position releases said grip of said first and second jaw sections on said EAS article attaching means to permit withdrawal of said EAS article attaching means from said first and second jaw sections, thereby releasing said EAS tag body from said EAS article attaching means.

28. A spring clamp in accordance with claim 27 wherein:

said first and second jaw sections of said jaw are integrally formed with said first and second parts of said clamp body and terminate in spaced facing edges, said spaced facing edges of said first and second jaw sections extending from a common first edge of said clamp body.

29. A spring clamp in accordance with claim 28 wherein:

said spaced facing edges of said first and second jaw sections extend from said common first edge of said clamp body inwardly toward each other, then curve to define an aperture for receiving said tack body and then terminate inwardly of a second edge of said clamp body.

30. A spring clamp in accordance with claim 29 wherein:

said first part of said clamp body extends to said common first edge and outward of said first jaw section;

and said second part of said clamp body extends to said common first edge and outward of said second jaw section.

31. A spring clamp in accordance with claim 30 wherein:

said first part of said clamp body includes an aperture by which said clamp body is mounted.

32. A spring clamp in accordance with claim 31 further comprising:

a spring arm extending along the length of said second edge of said clamp body;

and a curved joint joining said spring arm to an end of said second edge of said clamp body adjacent said first part of said clamp body.

33. A detaching device for use in detaching an EAS from an article, said EAS tag including: a tag body; means for attaching said tag body to an article, said attaching means having a part which is received in said tag body; means within said tag body for releasably preventing said part of said attaching means form being withdrawn from said tag body; means within said tag body defining an arcuate channel leading from the exterior of said tag body to said preventing means; and an EAS sensor; said detaching device comprising:

an arcuate probe configured to be received in and guided by said arcuate channel of said tag body; and

means for moving said arcuate probe, whereby said arcuate probe is introduced into and guided by said arcuate channel to said preventing means in said tag body for releasing said preventing means from preventing said part of said attaching means from being withdrawn for said tag body, said arcuate probe being withdrawn from said tag body through said arcuate channel.

34. A detaching device in accordance with claim wherein:

said means for moving said probe causes said probe to rotate.

35. A detaching device in accordance with claim 34 further comprising:

means for mounting said EAS tag relative to said arcuate probe, whereby rotation of said arcuate probe in first and second opposite rotation directions by said moving means results in said probe being introduced into and guided by and being withdrawn from said arcuate channel of said tag body.

36. A detaching device in accordance with claim 35 wherein

said moving means is hand actuated.

37. A detaching device in accordance with claim 36 further comprising:

a hand actuated trigger;

and mechanical linkage means linking said hand actuated trigger to said moving means.

38. A detaching device in accordance with claim **35** wherein

said moving means is actuated by said EAS tag.

39. A detaching device in accordance with claim **38** wherein:

said moving means includes: motor means coupled to said arcuate probe for rotating said arcuate probe in said first and second directions; and electronics means for controlling said motor means including means for sensing the position of said tag body and the position of said arcuate probe.

40. A detaching device in accordance with claim **39** wherein:

said means for sensing the position of said tag body and the position of said arcuate probe includes: a first sensor for sensing one or more parts of said tag body upon said EAS tag being mounted on said mounting means, said first sensor upon sensing the presence of said one or more parts of said tag body causing said electronics means to control said motor means to rotate said arcuate probe in said first direction from a first position to cause said arcuate probe to pass into said arcuate channel; a second sensor for sensing when said arcuate probe has moved to a second position upon rotation of said arcuate probe in said first direction, said second sensor upon sensing that said arcuate probe has moved to said second position causing said electronics means to control said motor means to rotate said arcuate probe in said second direction to cause said probe to be withdrawn from said arcuate channel; and a third sensor for sensing when said arcuate probe has moved to said first position upon rotation of said arcuate probe in said second direction, said third sensor upon sensing that said arcuate probe has moved to said first position causing said electronics means to control said motor means to stop rotation of said arcuate probe.

41. A detaching device in accordance with claim **34** wherein:

said arcuate probe has a first cross section over a first length of said arcuate probe and a second cross section over a second length of said arcuate probe.

42. A detaching device in accordance with claim **41** wherein:

said first cross section is substantially rectangular; and said second cross section is substantially L-shaped.

43. A detaching device in accordance with claim **42** wherein:

said second length is at the forward end of said probe.

44. A method of detaching an EAS tag from an article, said EAS tag comprising: a tag body; means for attaching said tag body to an article, said attaching means having a part which is received in said tag body; means within said tag body for releasably preventing said part of said attaching means from being withdrawn from said tag body; and means within said tag body defining an arcuate channel leading from the exterior of said tag body to said preventing means; said method comprising:

providing an arcuate probe configured to be received in and guided by said arcuate channel of said tag body;

and moving said arcuate probe, whereby said arcuate probe is introduced into and guided by said arcuate channel to said preventing means in said tag body for releasing said preventing means from preventing said part of said attaching means from being withdrawn from said tag body, and said arcuate probe is withdrawn from said tag body through said arcuate channel.

45. A method in accordance with claim **44** wherein:

said moving of said arcuate probe includes rotating said arcuate probe.

46. An EAS system comprising:

an EAS tag attached to an article; said EAS tag comprising: a tag body; means for attaching said tag body to an article, said attaching means having a part which is received in said tag body; means within said tag body for releasably preventing said part of said attaching means from being withdrawn from said tag body; means within said tag body defining an arcuate channel leading from the exterior of said tag body to said preventing means, said arcuate channel being adapted to receive and guide an arcuate probe to said preventing means for releasing said preventing means from preventing said part of said attaching means for being withdrawn from said tag body; and an EAS sensor;

means for transmitting a first signal into a surveillance zone; and

means for receiving a tag signal resulting from the interaction in said zone of said first signal with EAS sensor in said tag for detecting the presence of said tag and article in said zone.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,426,419 **Page 1 of 2**

DATED : June 20, 1995

INVENTOR(S) : Thang T. Nguyen et al.

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

Col. 5, line 29 Change "provide" to -- provided --.

Col. 5, line 31 Change "4B" to --4 and--.

Col. 10, line 22 Delete "detectable".

Col. 14, line 28 After "EAS" insert -- tag --.

Col. 14, line 33 Change "form" to -- from --.

Col. 14, line 46 Change "for" to -- from --.

Col. 14, line 50 After "claim" insert -- 33 --.

Col. 14, line 64 After "wherein" insert -- : --.

Col. 15, line 4 After "wherein" insert -- : --.

Col. 16, line 43 Change "for" to -- from --.

Col. 16, line 48 After "with" insert -- said --.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,426,419

Page 2 of 2

DATED : June 20, 1995

INVENTOR(S) : Thang T. Nguyen et al.

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

Col. 5, line 30, insert --4B-- after body; and Col. 5, line 32, after tag insert --1--.

Signed and Sealed this

Seventeenth Day of October, 1995

Attest:

Bruce Lehman

BRUCE LEHMAN

Attesting Officer

Commissioner of Patents and Trademarks

US006118378A

United States Patent [19]

Balch et al.

[11] **Patent Number: 6,118,378**

[45] **Date of Patent: Sep. 12, 2000**

[54] **PULSED MAGNETIC EAS SYSTEM INCORPORATING SINGLE ANTENNA WITH INDEPENDENT PHASING**

[75] Inventors: **Brent F. Balch**, Fort Lauderdale; **Stephen W. Embling**, Pompano Beach; **Ming-Ren Lian**, Boca Raton, all of Fla.

[73] Assignee: **Sensormatic Electronics Corporation**, Boca Raton, Fla.

[21] Appl. No.: **08/969,928**

[22] Filed: **Nov. 28, 1997**

[51] **Int. Cl.**[7] **H04Q 1/00**

[52] **U.S. Cl.** **340/572.7**; 343/742; 343/867

[58] **Field of Search** 340/572.7, 10.2; 343/742, 867

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Primary Examiner—Brian Zimmerman
Attorney, Agent, or Firm—Quarles & Brady LLP

[57] **ABSTRACT**

A single antenna transmits and receives signals. The single antenna has first and second antenna loops substantially lying in a common plane and partially overlapping. First and second transceiver circuits are coupled to the first and second antenna loops respectively, for respectively generating in a first mode of operation first and second pulsed magnetic fields together defining an interrogation zone for a marker generating a characteristic response to the magnetic fields in the interrogation zone, and for receiving signals from the interrogation zone in a second mode of operation. The first and second transceiver circuits alternately generate the first and second magnetic fields substantially in phase with one another and substantially out of phase with one another. The partially overlapping antenna loops prevent detuning of the transceivers otherwise resulting from the phase alternating. Each of the first and second transceiver circuits has a phase controllable transmitter section and a phase controllable receiver section. A controller independently phase controls the transmitter and receiver sections. Each receiver section is coupled across the tuned circuit of its respective transceiver circuit.

23 Claims, 3 Drawing Sheets

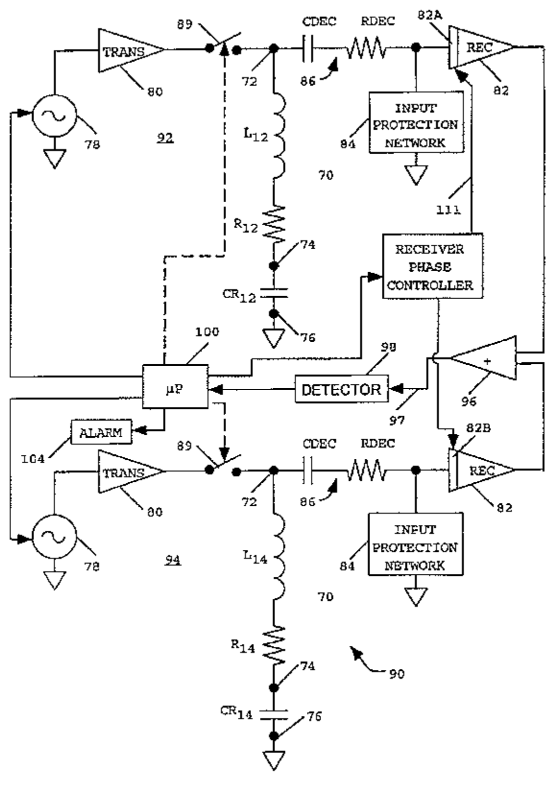


EXHIBIT 2

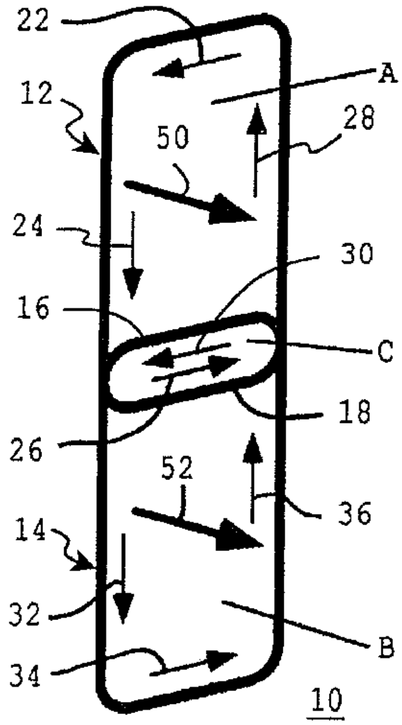


FIG. 1

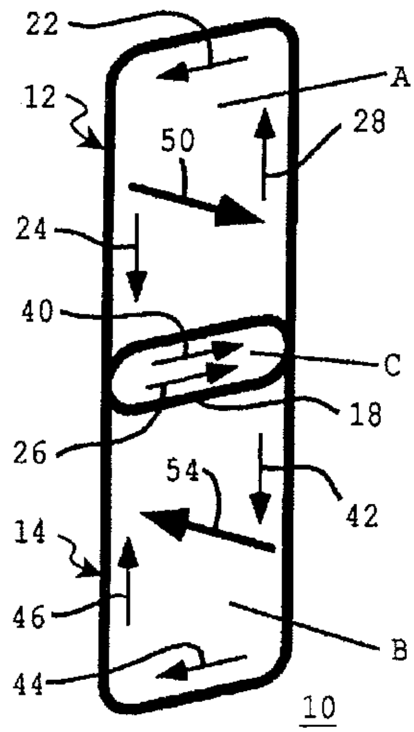


FIG. 2

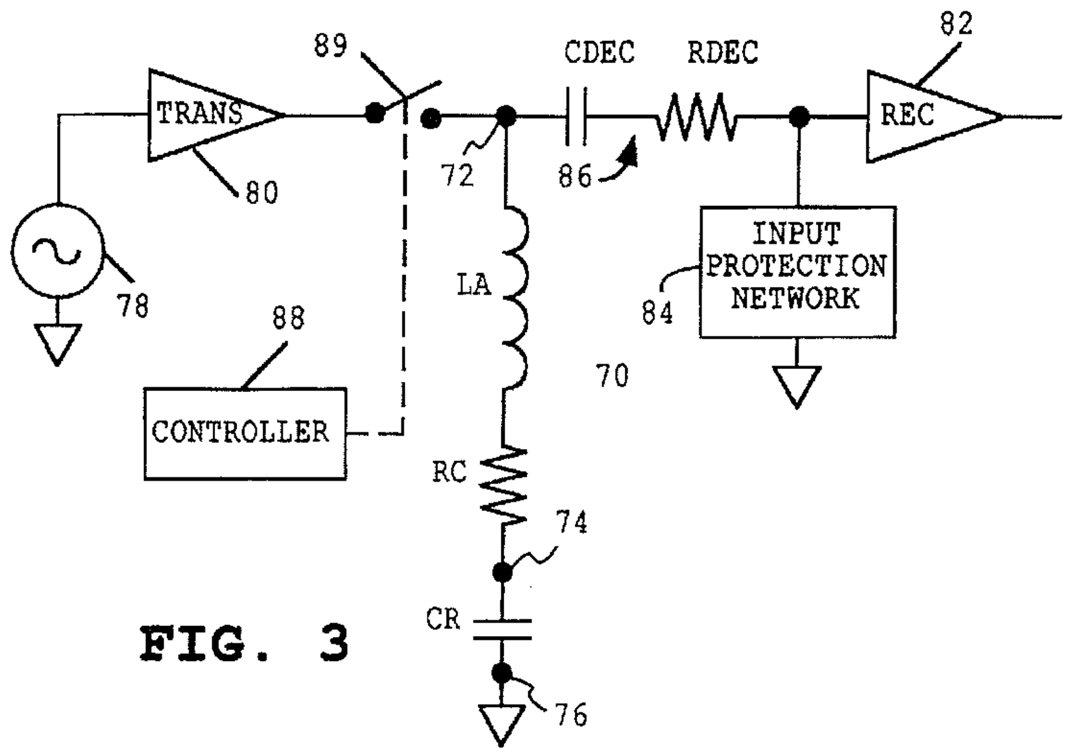
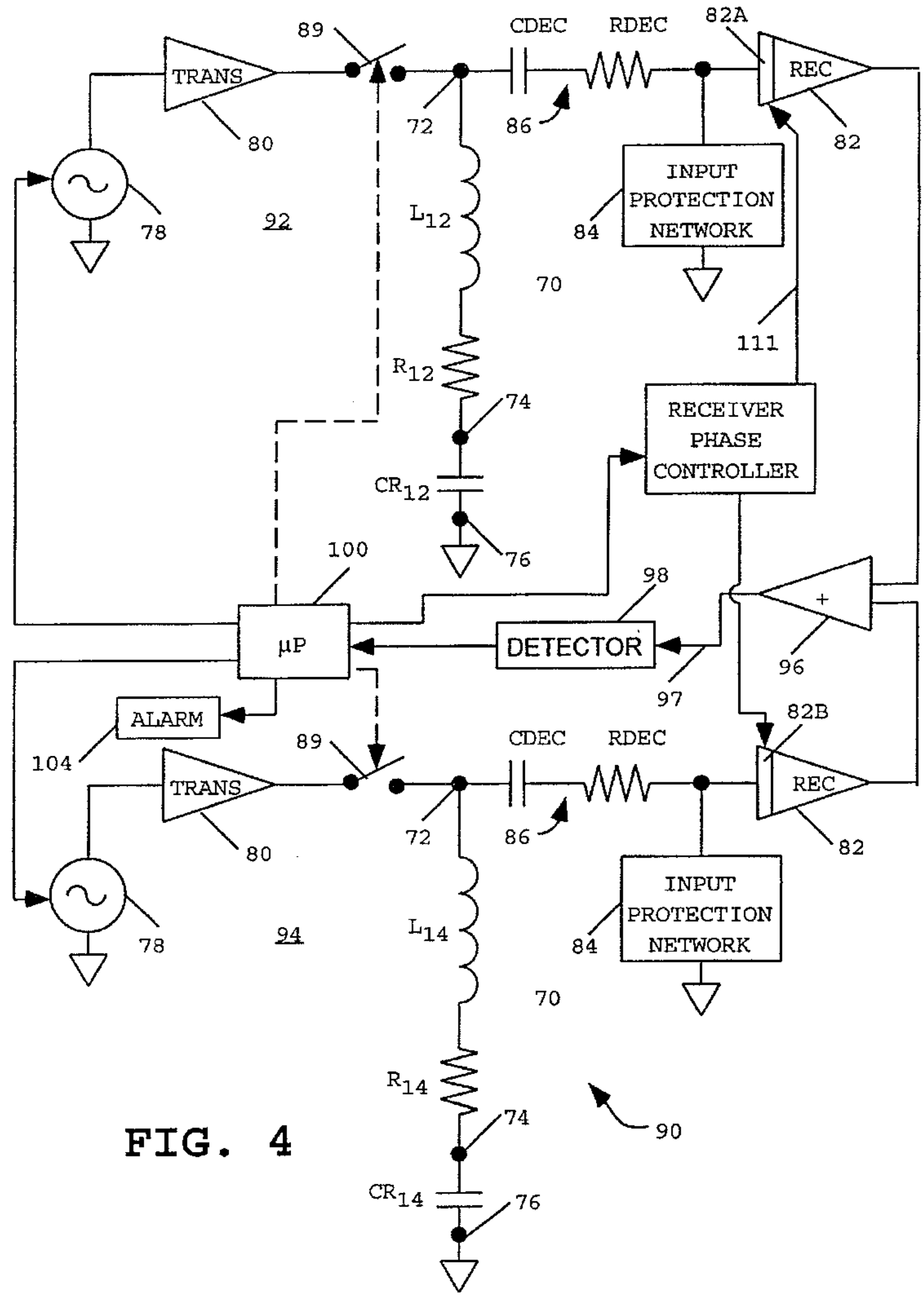


FIG. 3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RDEC
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TRANS
REC
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92
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R_{12}
74
RECEIVER PHASE CONTROLLER
CR_{12}
76
100
98
+
μP
DETECTOR
96
97
ALARM
82B
104
89
CDEC
RDEC
TRANS
REC
72
86
80
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INPUT PROTECTION NETWORK
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94
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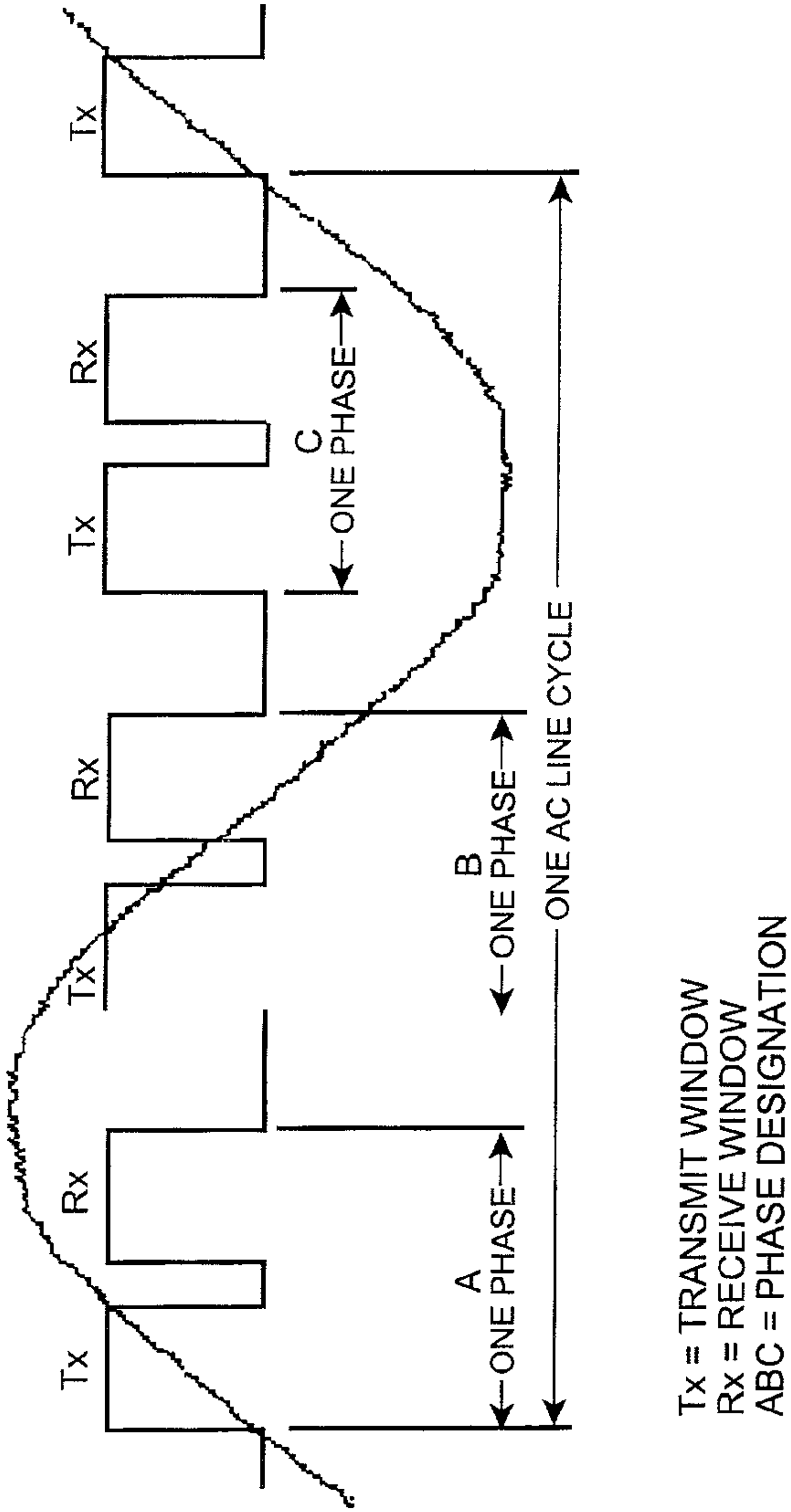
90
CR_{14}
76

FIG. 4


Tx
Rx
Tx
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Tx
Rx
Tx
C
ONE PHASE
B
ONE PHASE
A
ONE PHASE
ONE AC LINE CYCLE
Tx = TRANSMIT WINDOW
Rx = RECEIVE WINDOW
ABC = PHASE DESIGNATION

FIG. 5

PULSED MAGNETIC EAS SYSTEM INCORPORATING SINGLE ANTENNA WITH INDEPENDENT PHASING

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of pulsed magnetic electronic article surveillance (EAS) systems in general, and in particular, to pulsed magnetic EAS systems having one antenna for both transmitting and receiving with independent phasing.

2. Description of Related Art

In conventional EAS systems, transmit and receive functions are provided by separate antenna coils. The need for separate antenna coils is problematic. The manufacturing cost is higher due to the additional material cost, assembly and test time, as well as the additional documentation and quality checking that is required.

The transmit and receive fields sometimes do not coincide. As an example, when a tag or marker is located in an orientation or location wherein it is sufficiently stimulated by the transmit antenna field, the tag or marker may not be simultaneously in an orientation or location wherein the tag or marker can be optimally interrogated by the receive antenna.

In transceiver antenna assemblies, especially those wherein separate transmit and receive coils operate in close proximity, the magnetic field produced by the transmit coil induces a current in the nearby receiver coil. This current in the receiver coil can be significant due to the low impedance of protective shunting devices commonly employed to protect the receiver input from damaging potentials due to transformer action between the two coupled coils. This induced current flowing in the receiver coil produces a magnetic field of its own, which is in opposition to the field produced by the transmit antenna. Due to the interaction of the opposing fields produced by the transmit antenna and the receive antenna, the net magnetic field in the interrogation zone is diminished, resulting in a loss of efficiency and requiring higher transmitter power to establish the desired field strength.

In conventional EAS systems employing multiple transmitter coils, the transmitter field phasing relationship is fixed or selectable during the installation process. Accordingly, it is possible for a tag or marker to pass through the interrogation zone in an orientation or location such that it is not sufficiently stimulated to be detected by the receive antennas. Transmitter antennas used in magnetic EAS systems must typically be configured as resonant circuits in order to develop enough current to provide sufficient field strength for proper operation. When multiple transmit coils are operated in close proximity, their fields interact, resulting in impedance changes in each coil. Once multiple transmit antennas are tuned to resonance for a particular phase relationship, if this phase relationship is changed significantly, each of the coils will no longer be at its resonant peak and each coil's current will be reduced by an amount depending on the magnitude of the phase difference, the individual coil's quality factor (Q) and the coefficient of coupling between the respective coils. In a multi-coil transmitter antenna, the transmitter coils must be resonated or tuned each time the field phasing changes substantially.

Most existing EAS systems utilize separate antenna coils for the transmit and receive functions of the system. The transmitter field phase relationship between coils is either

fixed or, if electronically controlled, held constant during system operation.

The Ultra*Max product line available from Sensormatic Electronics Corporation does include a DoubleChecker device for reminding clerks to remove or deactivate magnetic labels or markers from protected items during the checkout process. The terms Ultra*Max and DoubleChecker are trademarks of Sensormatic Electronics Corporation. The antenna used in the DoubleChecker performs a dual function, but is conceptually and electrically different from the single transmit and receive antenna implementations explained above, and is unsuitable for use in a full system due to prohibitive reactive voltages.

A coplanar single coil dual function transmit and receive antenna for a proximate surveillance system is shown in U.S. Pat. No. 4,963,880 and comprises: a single coil having a perimeter and enclosing a unique region; means for driving the coil during the transmit intervals to generate and transmit time varying magnetic field components within the proximate region, the coil being driven on, producing components vertical and horizontal to the plane of the coil, which components are the result of fringing effects within the area approximated by the coil perimeter; circuit means connected to the coil for forming with the coil, during the transmit intervals, a series resonant tuned circuit and, during the receive intervals, an untuned circuit; and, tristate output switched-mode operating means connected to the circuit means for providing an intrinsic automatic changeover of the circuit means between the tuned and untuned circuits.

Some pulsed magnetic EAS systems, for example those available from Sensormatic Corporation, synchronize their operation by sensing the local power line positive zero crossings, as shown in FIG. 5. Each line cycle is divided up into six alternating time windows: three windows for transmission and three windows for reception. The first transmit-receive window sequential pair occurs at 0° with respect to the zero crossing, the second first transmit-receive window sequential pair occurs at 120° with respect to the zero crossing and the third first transmit-receive window sequential pair occurs at 240° with respect to the zero crossing.

SUMMARY OF THE INVENTION

The EAS system in accordance with the inventive arrangements taught herein represents an improvement over previous designs in allowing the same antenna coil for both transmit and receive functions, while at the same time permitting independent phasing relationships between transmit and receive functions with regard to other system antenna coils, resulting in significant performance enhancement as well as cost savings.

Additionally, the unique coil arrangement allows the field phase from multiple transmitter coils to change substantially without changing their resonant frequency and without a resulting loss in transmitter current.

An electronic article surveillance system, in accordance with an inventive arrangement, comprises: an antenna having first and second antenna loops; first and second transceiver circuits coupled to the first and second antenna loops respectively, for respectively generating in a first mode of operation first and second magnetic fields together defining an interrogation zone for a marker generating a characteristic response to the magnetic fields in the interrogation zone, and for receiving signals from the interrogation zone in a second mode of operation; the first and second transceiver circuits, when transmitting, alternately generating the first and second magnetic fields substantially in phase with

one another and substantially out of phase with one another; and, a detector for evaluating an output signal, representative of the signals received by the first and second transceiver circuits from the interrogation zone, for the characteristic response of the marker.

Advantageously, the first and second antenna loops substantially lie in a common plane and partially overlap.

The first transceiver circuit comprises: a first signal generator; a first receiver; and, a first transmitter responsive to the first signal generator and coupled to the first antenna loop and to the first receiver. The second transceiver circuit comprises: a second signal generator; a second receiver; and, a second transmitter responsive to the second signal generator and coupled to the second antenna loop and to the second receiver.

The system can advantageously further comprise a controller for the first and second transceiver circuits, the controller being responsive to the detector. The controller advantageously establishes the alternating generation of the magnetic field phases when the characteristic response is not sensed and stops the alternating generation when the characteristic response is first sensed, whereby the phase relationship of the fields in which the marker is first sensed is maintained until the characteristic response is confirmed or not established. The controller can advantageously comprise a microprocessor.

An electronic article surveillance system in accordance with another inventive arrangement comprises: an antenna having first and second antenna loops, the first and second antenna loops substantially lying in a common plane and partially overlapping; first and second transceiver circuits coupled to the first and second antenna loops respectively, the first and second transceiver circuits, when transmitting, alternately generating the first and second magnetic fields substantially in phase with one another and substantially out of phase with one another, the partial overlapping of the first and second antenna loops substantially preventing detuning the first and second loops; and, a detector for evaluating an output signal representative of signals received by the first and second transceiver circuits.

The system can advantageously further comprise a controller for the first and second transceiver circuits, the controller being responsive to the detector. The controller advantageously establishes the alternating generation of the magnetic field phases when the characteristic response is not sensed and stops the alternating generation when the characteristic response is first sensed, whereby the phase relationship of the fields in which the marker is first sensed is maintained until the characteristic response is confirmed or not established. The controller can advantageously comprises a microprocessor.

An electronic article surveillance system in accordance with yet another inventive arrangement comprises: an antenna having first and second antenna loops; first and second transceiver circuits coupled to the first and second antenna loops respectively; the first and second transceiver circuits, when transmitting, alternately generating first and second magnetic fields substantially in phase with one another and substantially out of phase with one another; a detector for evaluating an output signal, representative of the signals received by the first and second transceiver circuits from the interrogation zone, for a characteristic response of a marker to the magnetic fields; and, a microprocessor for controlling the first and second transceiver circuits, the controller being responsive to the detector.

The microprocessor advantageously establishes the alternating generation of the magnetic field phases when the characteristic response is not sensed and stops the alternating generation when the characteristic response is first sensed, whereby the phase relationship of the fields in which the marker is first sensed is maintained until the characteristic response is confirmed or not established.

In accordance with yet another inventive arrangement, an electronic article surveillance system comprises: a single antenna for transmitting and receiving signals, the single antenna having first and second antenna loops; first and second transceiver circuits coupled to the first and second antenna loops respectively, for respectively generating in a first mode of operation first and second pulsed magnetic fields together defining an interrogation zone for a marker generating a characteristic response to the magnetic fields in the interrogation zone, and for receiving signals from the interrogation zone in a second mode of operation; and, the first and second transceiver circuits, when transmitting, alternately generating the first and second magnetic fields substantially in phase with one another and substantially out of phase with one another.

Each of the first and second transceiver circuits comprises a tuned circuit and a receiver section, the receiver section being advantageously coupled across the tuned circuit.

In accordance with yet another inventive arrangement, an electronic article surveillance system comprises: an antenna having first and second antenna loops; first and second transceiver circuits coupled to the first and second antenna loops respectively, for respectively generating in a first mode of operation first and second pulsed magnetic fields together defining an interrogation zone for a marker generating a characteristic response to the magnetic fields in the interrogation zone, and for receiving signals from the interrogation zone in a second mode of operation; each of the first and second transceiver circuits having a phase controllable transmitter section and a phase controllable receiver section; and, a controller for independently phase controlling the transmitter and receiver sections.

In accordance with yet another inventive arrangement, an electronic article surveillance system comprises: an antenna having first and second antenna loops substantially lying in a common plane and partially overlapping; first and second transmitter circuits coupled to the first and second antenna loops respectively, for respectively generating in a first mode of operation first and second pulsed magnetic fields together defining an interrogation zone for a marker generating a characteristic response to the magnetic fields in the interrogation zone; and, the first and second transmitter circuits, when transmitting, alternately generating the first and second magnetic fields substantially in phase with one another and substantially out of phase with one another, the partially overlapping antenna loops preventing detuning of the transmitters otherwise resulting from the phase alternating.

In accordance with yet another inventive arrangement, an electronic article surveillance system comprises: a single antenna for transmitting and receiving signals, the single antenna having first and second antenna loops substantially lying in a common plane and partially overlapping; first and second transceiver circuits coupled to the first and second antenna loops respectively, for respectively generating in a first mode of operation first and second pulsed magnetic fields together defining an interrogation zone for a marker generating a characteristic response to the magnetic fields in the interrogation zone, and for receiving signals from the interrogation zone in a second mode of operation; and, the first and second transceiver circuits, when transmitting, alternately generating the first and second magnetic fields

substantially in phase with one another and substantially out of phase with one another, the partially overlapping antenna loops preventing detuning of the transceivers otherwise resulting from the phase alternating.

Advantageously, the system can further comprise: each of the first and second transceiver circuits having a phase controllable transmitter section and a phase controllable receiver section; and, a controller for independently phase controlling the transmitter and receiver sections.

Advantageously, each of the first and second transceiver circuits comprises a tuned circuit, the respective receiver section of each the transceiver circuit being coupled across the respective tuned circuit of each the transceiver circuit.

In each of the inventive arrangements, and insofar as single loops or coils are concerned, the single loops advantageously generate a magnetic field having a certain flux geometry during a transmitting mode of operation, the same certain flux geometry affecting the antenna in a receiving mode of operation. This is not always true for multiple loop or coil antennas. For instance, if the upper and lower loops or coils transmit in aiding mode, but during receive intervals the coils are configured in figure-8 mode, for noise rejection, then a horizontal marker located on the plane along the top-to-bottom center line would be strongly stimulated by the transmit field, but would be in a null zone for the figure-8 receiver antenna.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a combination transmitting and receiving antenna configuration in accordance with the inventive arrangements, in an in-phase or aiding mode of transmission.

FIG. **2** shows the combination transmitting and receiving antenna configuration of FIG. **1**, in an out-of-phase, figure-8 or opposing mode of transmission.

FIG. **3** is a block diagram of a transceiver circuit in accordance with the inventive arrangements for use with any one of the antenna loops shown in FIGS. **1** and **2**.

FIG. **4** is a block diagram of a transceiver circuit in accordance with the inventive arrangements for use with both loops of the antenna shown in FIGS. **1** and **2**.

FIG. **5** is a timing diagram useful for explaining the is operation of the transceiver circuits shown in FIGS. **3** and **4**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The two most common antenna configurations for EAS systems are a single, contiguous loop, which may be circular, oval, triangular or rectangular, and a "figure-8" loop as shown in FIGS. **1** and **2** respectively. The single rectangular loop configuration is also referred to as an in-phase or aiding configuration. The "figure-8" configuration is also referred to as an out-of-phase or opposing configuration. These configurations are implemented by using two adjacent loops, as shown, sometimes built into a pylon and sometimes built into a wall or other structure.

In FIG. **1**, antenna **10** has an upper loop **12** and a lower loop **14**. The loops **12** and **14** are driven by current flowing in the same direction. In loop **12**, the current is represented by arrows **22**, **24**, **26** and **28**. In loop **14**, the current is represented by arrows **30**, **32**, **34** and **36**. In accordance with the right-hand rule, current loops **12** and **14** generate magnetic fields oriented in the same direction, namely the direction indicated by arrows **50** and **52**, respectively. The current **26** in the bottom leg **18** of upper loop **12** and the current **30** in the top leg **16** of lower loop **14** flow in opposite directions. Accordingly, the respective fields generated by currents **26** and **30** mostly cancel out one another. The overall effect is that of a single, large rectangular loop. This is referred to as an in-phase or aiding mode of operation.

Typically, the lower leg **18** of upper loop **12** and the upper leg **16** of lower loop **14** coincide or substantially coincide with one another. In accordance with an inventive arrangement, the upper and lower loops **12** and **14** overlap one another vertically to define three zones or areas designated A, B and C. Zone A represents the effective area of only the upper loop **12**. Zone B represents the effective area of only the lower loop **14**. Zone C represents the effective area of the overlapped portions of the upper and lower loops.

In FIG. **2**, the upper loop **12** and a lower loop **14** of antenna **10** are driven by current flowing in opposite directions. In loop **12**, the current is represented by arrows **22**, **24**, **26** and **28**, as in FIG. **1**. In loop **14**, the current is represented by arrows **40**, **42**, **44** and **46**. In accordance with the right-hand rule, current loops **12** and **14** generate magnetic fields oriented in opposite directions, namely the directions indicated by arrows **50** and **54**, respectively. The current **26** in the bottom leg **18** of upper loop **12** and the current **40** in the top leg **16** of lower loop **14** flow in the same direction. Accordingly, the respective fields generated by currents **26** and **40** reinforce one another. The overall effect is that of two smaller rectangular loops which form a large "figure-**8**". This is referred to as an out-of-phase or opposing mode of operation.

In the aiding configuration of FIG. **1**, current flows in the same relative direction in both the upper and lower coil. Effectively, the sides bounding zone C cancel each other out and the antenna functions as if it were a single loop, nearly twice as long as the individual coils. Accordingly, the in-phase configuration will provide substantial horizontal magnetic field, but a significantly lower or even zero valued vertical component, that is a null zone or area, especially at the vertical center area C of the interrogation zone.

In the opposing configuration, the current flowing in the lower coil is in the opposite direction from that in the upper coil. The fields produced by the coils are in opposite directions, and there is a strong vertical component to the flux in the vicinity of zone C, due both to this opposition and the fact that each of the horizontal coil elements bounding zone C carry equal current in the same direction. Since these two members are physically close, they act in tandem as if they were a single element carrying twice the current of a single coil. The flux generated is in the same direction as the flux produced by the rest of each coil, so it is additive. Accordingly, in the out-of-phase transmitter configuration the vertical magnetic field becomes stronger but the horizontal component becomes weaker or even zero valued, also creating a null zone near area C.

Two current carrying coils placed in proximity to each other will produce fields which interact. These interacting fields, in turn, influence the parameters of each of the coils, such as their impedance, effective inductance and Q. If each coil is part of a resonant circuit, this proximal relationship affects the tuning of each individual circuit. Additionally, the direction of influence of each coil on the other reverses if the phase relationship is reversed. This leads to serious design problems if two coils are intended to be operated in close proximity, at resonance and with multiple phase conditions. If the antennas are tuned to resonance in one phase condition to maximize the current in the antennas, then reversing the direction of current in one of the coils reverses the phase of

its flux. Both antennas are de-tuned by an amount that varies with the areas of the coils, the orientation and distance between them, and the Q of the tuned circuits. This detuning results in a loss in coil current and corresponding magnetic field.

It has been discovered, however, that a special case exists wherein the tuning situation can be optimized. If the coils are arranged to have a controlled amount of overlap, as shown in zone C in FIGS. **1** and **2**, there is an optimal point wherein the field produced by zone C offsets the expected interaction between zones A and B. This optimum area relationship between zones A, B and C depends on the flux density in the area of overlap, the shape of the two coils, their geometrical relationship (that is, which two sides or corners overlap) and coil properties, such as the spacing between individual windings and the diameter of the overall wire bundle. For this reason, the optimum point is best determined empirically. The antennas are tuned individually and, while alternately reversing the direction of current in one of the coils, the magnitude of the coil current is monitored while the overlap between the coils is gradually increased and decreased. The optimum point is reached when the current is equal for either phase condition. For the two equal area, rounded rectangular coils **12** and **14** shown in FIGS. **1** and **2**, the optimum point has been found to occur when zone C is approximately 11% of the area of either coil.

The transceiver circuit **70** shown in FIG. **3** can be used in conjunction with each of the loops **12** and **14** of the antenna **10** shown in FIGS. **1** and **2** so that the antenna **10** can be used for both transmit and receive functions in an EAS system. A signal generator **78** supplies an input signal to a transmitter **80** at a desired frequency. The transmitter **80** drives a resonant antenna, for example antenna **10** represented by inductor L_A and resistor R_C, at sufficient current to produce the desired magnetic field in the EAS system's interrogation zone. The resonating capacitor C_R can functionally exchange places with the antenna coil L_A and the antenna coil's resistance R_C with no change in function. In a practical EAS system, the reactive voltage at resonance, between points nodes **72** and **74** or between nodes **74** and **76**, can easily exceed 1000 volts. At resonance, the coil current is equal to the driving voltage divided by the coil resistance, and the coil voltage is equal to the driving voltage times the antenna Q. Connecting the receiver circuitry across the antenna coil is impractical with these potentials. If, however, the receiver circuit **82** is connected directly to the output of the transmitter amplifier **80** and across the entire resonant antenna, the receiver is only exposed to the peak output voltage of the transmitter, on the order of tens of volts, which is a much more desirable situation. A decoupling network **84** between the transmitter output and the receiver input includes a capacitor C_{DEC} and a resistor R_{DEC}. The receiver is also protected by an input protection network **84**, which can comprise back to back diodes and a resistor as is known in the art. The values of the components will vary according to the frequency of operation.

In the circuit of FIG. **3** it can be seen that the relationship of the phase of the coil to the receiver input remains fixed with regard to signals magnetically coupled to the coil when the transmitter is off, regardless of the phase of the current in the coil produced by the transmitter. The receiver is coupled across the entire tuned circuit.

In accordance with the pulse mode of operation, the transmitter is coupled to the transceiver circuit through a switch that is responsive to a controller **88**. Controller **88** may be responsive to a microprocessor, or may itself be a microprocessor. The transmitter is decoupled form the correct except during transmission of the pulses.

Two duplicate single loop transceiver circuits **92** and **94** can be connected with a common ground, as shown by transceiver circuit **90** in FIG. **4**. Each of the circuits **92** and **94** is essentially identical to the transceiver circuit **70** shown in FIG. **3**, except that one of the circuits, for example circuit **94**, can transmit out of phase with the circuit **92**. The phase of the signal generators **78** in circuits **92** and **94** can be controlled by a microprocessor **98**. Transceiver circuit **92** is shown as being connected to the upper loop in FIGS. **1** and **2**, by designation of the inductor as L_{12}. Transceiver circuit **94** is shown as being connected to the lower loop in FIGS. **1** and **2**, by designation of the inductor as L_{14}.

The phase of the current in one of the coils L_{12} and L_{14} can be alternately reversed with respect to the other one of the coils L_{12} and L_{14}, while the phase of signals induced in the coils while in receive mode remains fixed. The fields generated by the respective loops have either substantially a 0° phase difference, as shown in FIG. **1**, or substantially a 180° phase difference, as shown in FIG. **2**. In this mode of operation, one of the antenna loops becomes a reference loop, or reference coil, with respect to the other loop, or coil. The signals from receivers **82** and **84** can be summed by operational amplifier **96** into a common signal on line **97** representing the ambient field seen by both loops **12** and **14**.

Phase control circuitry **110** can be advantageously included, controlled by a microprocessor **100**, to independently change the phase of signals passing through input stages **82A** and **82B** of receivers **82** in circuits **92** and **94** respectively, such that the composite signal on line **97** can preferentially represent sum or difference signal components.

The ambient field signal is an input to a detector **98**, which evaluates the ambient field signal to determine if a marker or tag is in the interrogation zone. The output of the detector **98** is an input to the microprocessor **100**. An alarm indicator **104** can be activated by the microprocessor as shown, or alternatively, by an output from the detector **98**, not shown.

In a more general case, receiver input stages **82A** and **82B** might each be connected to separate input detectors **98**, and their respective phase and amplitude relationships determined by microprocessor **100** under software control.

This ability to independently reverse the phase of one of the transmitter coils is particularly advantageous because, as noted above, depending on the coil phase relationship, magnetic markers in some orientations and locations within the system's interrogation zone may not be adequately stimulated to produce a response in the null zones or areas. If the phase of one of the coils is reversed, these null areas change location and/or orientation, such that if a marker is in a null area for one relative phase condition, it will not be in a null area for the other relative phase condition. System software in the microprocessor **100** can control the relative transmitter phasing in such a way as to alternate between aiding, or in-phase, and opposing, or out-of-phase relative phase conditions of the transceiver circuits **92** and **94** until such time that a magnetic marker response is first sensed. Upon such first sensing, the phase relationship is held fixed until such time as a validation sequence is either successfully completed and an alarm generated, or the sequence fails, after which the transmitters return to alternating mode.

An EAS system using a single coil for both transmit and receive functions, with independent phase control, provides a significant performance improvement, allowing lower transmitter power and optimal field relationships between transmit and receive functions. If a magnetic marker is located within the system's interrogation zone in such a

location and orientation that it is optimally stimulated by the magnetic field generated by an antenna, then it is simultaneously in an optimum orientation for its response signal to be received by the same antenna. Such an EAS system also entails lower manufacturing costs and better performance than existing designs.

What is claimed is:

1. An electronic article surveillance system, comprising:

an antenna having first and second antenna loops;

first and second transceiver circuits coupled to said first and second antenna loops respectively, for respectively generating in a first mode of operation first and second magnetic fields together defining an interrogation zone for a marker generating a characteristic response to said magnetic fields in said interrogation zone, and for receiving signals from said interrogation zone in a second mode of operation;

said first and second transceiver circuits, when transmitting, alternately generating said first and second magnetic fields substantially in phase with one another and substantially out of phase with one another; and,

a detector for evaluating an output signal, representative of said signals received by said first and second transceiver circuits from said interrogation zone, for said characteristic response of said marker.

2. The system of claim 1, wherein said first and second antenna loops substantially lie in a common plane and partially overlap.

3. The system of claim 1, wherein said first transceiver circuit comprises:

a first signal generator;

a first receiver; and,

a first transmitter responsive to said first signal generator and coupled to said first antenna loop and to said first receiver.

4. The system of claim 3, wherein said second transceiver circuit comprises:

a second signal generator;

a second receiver; and,

a second transmitter responsive to said second signal generator and coupled to said second antenna loop and to said second receiver.

5. The system of claim 1, further comprising a controller for said first and second transceiver circuits, said controller being responsive to said detector.

6. The system of claim 1, wherein said controller establishes said alternating generation of said magnetic field phases when said characteristic response is not sensed and stops said alternating generation when said characteristic response is first sensed, whereby said phase relationship of said fields in which said marker is first sensed is maintained until said characteristic response is confirmed or not established.

7. The system of claim 6, wherein said controller comprises a microprocessor.

8. The system of claim 1, wherein said antenna generates a magnetic field having a certain flux geometry during said first mode of operation, said same certain flux geometry affecting said antenna in said second mode of operation.

9. An electronic article surveillance (EAS) system, comprising:

an antenna having first and second antenna loops, said first and second antenna loops substantially lying in a common plane and partially overlapping;

first and second transceiver circuits coupled to said first and second antenna loops respectively, said first and second transceiver circuits, when transmitting, alternately generating said first and second magnetic fields substantially in phase with one another and substantially out of phase with one another, said partial overlapping of said first and second antenna loops substantially preventing detuning said first and second loops; and,

a detector for evaluating an output signal representative of signals received by said first and second transceiver circuits.

10. The system of claim 9, further comprising a controller for said first and second transceiver circuits, said controller being responsive to said detector.

11. The system of claim 10, wherein said controller establishes said alternating generation of said magnetic field phases when said characteristic response is not sensed and stops said alternating generation when said characteristic response is first sensed, whereby said phase relationship of said fields in which said marker is first sensed is maintained until said characteristic response is confirmed or not established.

12. The system of claim 11, wherein said controller comprises a microprocessor.

13. The system of claim 1, wherein said antenna generates a magnetic field having a certain flux geometry during a transmitting mode of operation, said same certain flux geometry affecting said antenna in a receiving mode of operation.

14. An electronic article surveillance (EAS) system, comprising:

an antenna having first and second antenna loops;

first and second transceiver circuits coupled to said first and second antenna loops respectively;

said first and second transceiver circuits, when transmitting, alternately generating first and second magnetic fields substantially in phase with one another and substantially out of phase with one another;

a detector for evaluating an output signal, representative of said signals received by said first and second transceiver circuits from said interrogation zone, for a characteristic response of a marker to said magnetic fields; and,

a microprocessor for controlling said first and second transceiver circuits, said controller being responsive to said detector.

15. The system of claim 14, wherein said microprocessor establishes said alternating generation of said magnetic field phases when said characteristic response is not sensed and stops said alternating generation when said characteristic response is first sensed, whereby said phase relationship of said fields in which said marker is first sensed is maintained until said characteristic response is confirmed or not established.

16. The system of claim 14, wherein said antenna generates a magnetic field having a certain flux geometry during a transmitting mode of operation, said same certain flux geometry affecting said antenna in a receiving mode of operation.

17. An electronic article surveillance system, comprising:

a single antenna for transmitting and receiving signals, said single antenna having first and second antenna loops;

first and second transceiver circuits coupled to said first and second antenna loops respectively, for respectively

generating in a first mode of operation first and second pulsed magnetic fields together defining an interrogation zone for a marker generating a characteristic response to said magnetic fields in said interrogation zone, and for receiving signals from said interrogation zone in a second mode of operation; and,

said first and second transceiver circuits, when transmitting, alternately generating said first and second magnetic fields substantially in phase with one another and substantially out of phase with one another.

18. The system of claim 17, wherein each of said first and second transceiver circuits comprises a tuned circuit and a receiver section, said receiver section being coupled across said tuned circuit.

19. An electronic article surveillance system, comprising:

an antenna having first and second antenna loops;

first and second transceiver circuits coupled to said first and second antenna loops respectively, for respectively generating in a first mode of operation first and second pulsed magnetic fields together defining an interrogation zone for a marker generating a characteristic response to said magnetic fields in said interrogation zone, and for receiving signals from said interrogation zone in a second mode of operation;

each of said first and second transceiver circuits having a phase controllable transmitter section and a phase controllable receiver section; and,

a controller for independently phase controlling said transmitter and receiver sections.

20. An electronic article surveillance system, comprising:

an antenna having first and second antenna loops substantially lying in a common plane and partially overlapping;

first and second transmitter circuits coupled to said first and second antenna loops respectively, for respectively generating in a first mode of operation first and second pulsed magnetic fields together defining an interrogation zone for a marker generating a characteristic response to said magnetic fields in said interrogation zone; and,

said first and second transmitter circuits, when transmitting, alternately generating said first and second magnetic fields substantially in phase with one another and substantially out of phase with one another, said partially overlapping antenna loops preventing detuning of said transmitters otherwise resulting from said phase alternating.

21. An electronic article surveillance system, comprising:

a single antenna for transmitting and receiving signals, said single antenna having first and second antenna loops substantially lying in a common plane and partially overlapping;

first and second transceiver circuits coupled to said first and second antenna loops respectively, for respectively generating in a first mode of operation first and second pulsed magnetic fields together defining an interrogation zone for a marker generating a characteristic response to said magnetic fields in said interrogation zone, and for receiving signals from said interrogation zone in a second mode of operation; and,

said first and second transceiver circuits, when transmitting, alternately generating said first and second magnetic fields substantially in phase with one another and substantially out of phase with one another, said partially overlapping antenna loops preventing detuning of said transceivers otherwise resulting from said phase alternating.

22. The system of claim 21, further comprising:

each of said first and second transceiver circuits having a phase controllable transmitter section and a phase controllable receiver section; and,

a controller for independently phase controlling said transmitter and receiver sections.

23. The system of claim 22, wherein each of said first and second transceiver circuits comprises a tuned circuit, said respective receiver section of each said transceiver circuit being coupled across said respective tuned circuit of each said transceiver circuit.

* * * * *

US006700490B2

(12) United States Patent
Frederick

(10) Patent No.: **US 6,700,490 B2**
(45) Date of Patent: **Mar. 2, 2004**

(54) **DIGITAL DETECTION FILTERS FOR ELECTRONIC ARTICLE SURVEILLANCE**

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(73) Assignee: **Sensormatic Electronics Corporation**, Boca Raton, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 180 days.

(21) Appl. No.: **10/104,829**

(22) Filed: **Mar. 22, 2002**

(65) **Prior Publication Data**

US 2002/0135482 A1 Sep. 26, 2002

Related U.S. Application Data

(60) Provisional application No. 60/278,805, filed on Mar. 26, 2001.

(51) **Int. Cl.**^{7} **G08B 13/14**

(52) **U.S. Cl.** **340/572.4**; 340/10.1; 375/343; 708/314; 708/422

(58) **Field of Search** 340/572.4, 572.1, 340/10.1, 10.3, 10.4; 342/42; 708/422, 314; 375/261, 340, 343, 350; 455/130; 702/66

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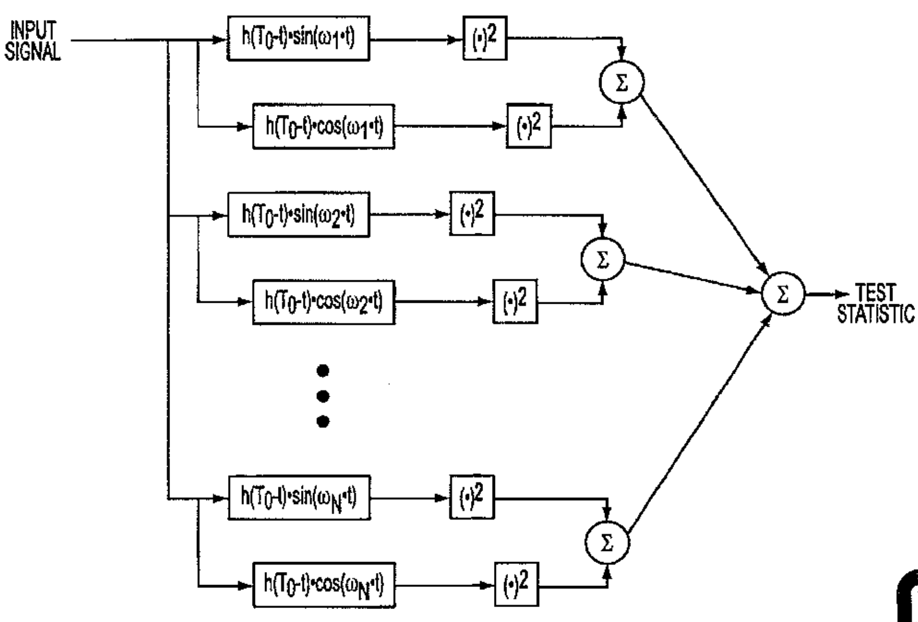
Primary Examiner—Benjamin C. Lee

(57) **ABSTRACT**

Digital implementation of electronic article surveillance (EAS) detection filtering for pulsed EAS systems is provided. Embodiments include direct implementation as a quadrature matched filter bank, as an envelope detector, a correlation receiver, and as a discrete Fourier transform. Pre-detection nonlinear filtering is also provided for impulsive noise environments.

22 Claims, 13 Drawing Sheets



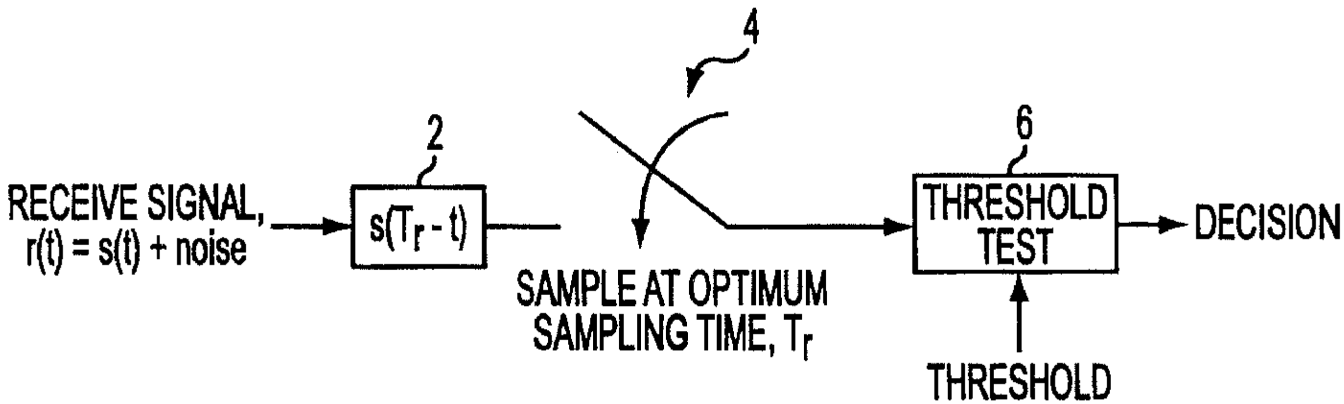


FIG. 1
(PRIOR ART)

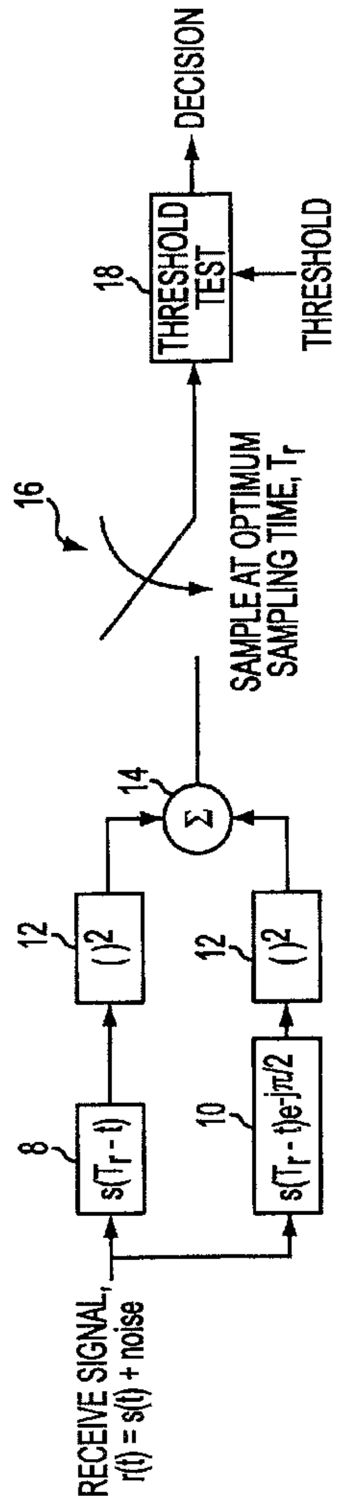


FIG. 2
(PRIOR ART)

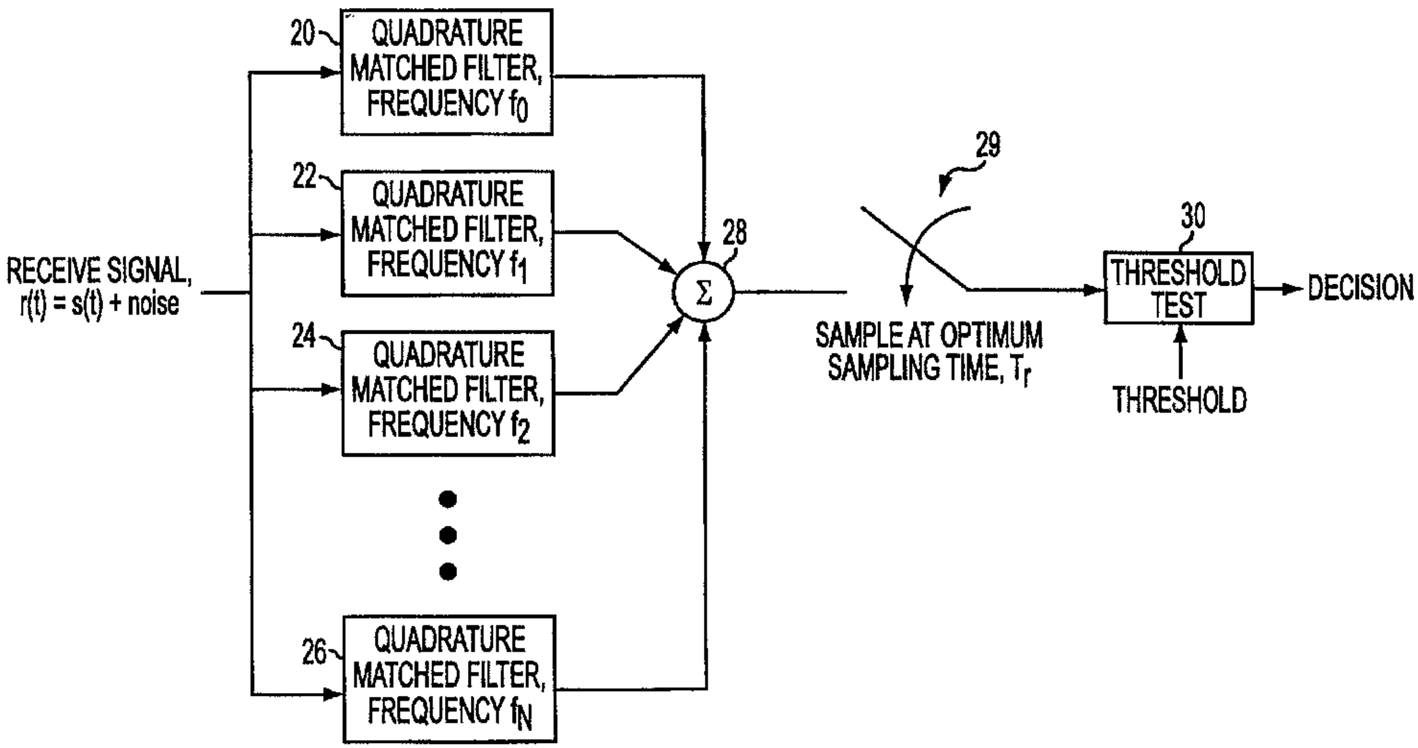


FIG. 3
(PRIOR ART)

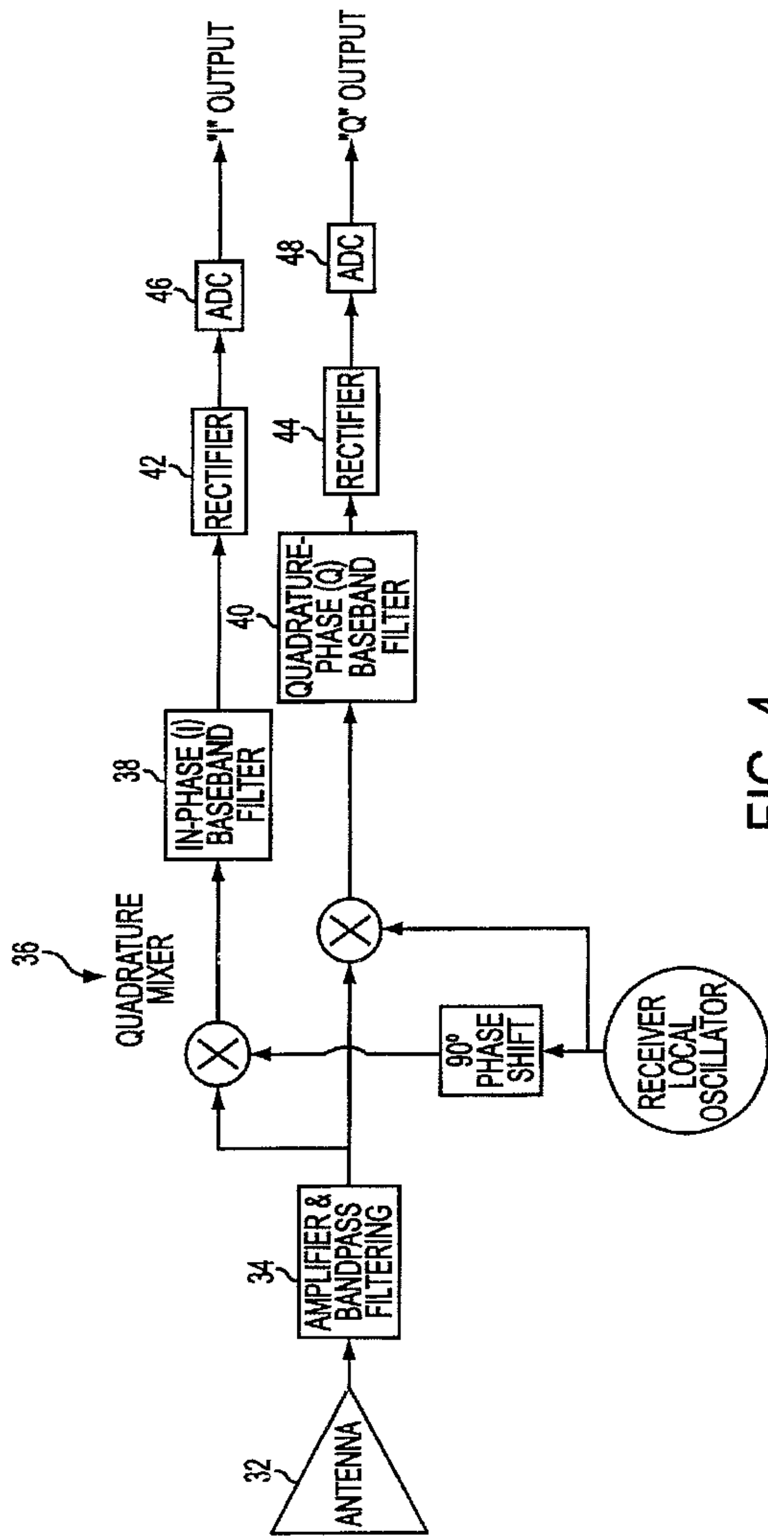


FIG. 4
(PRIOR ART)

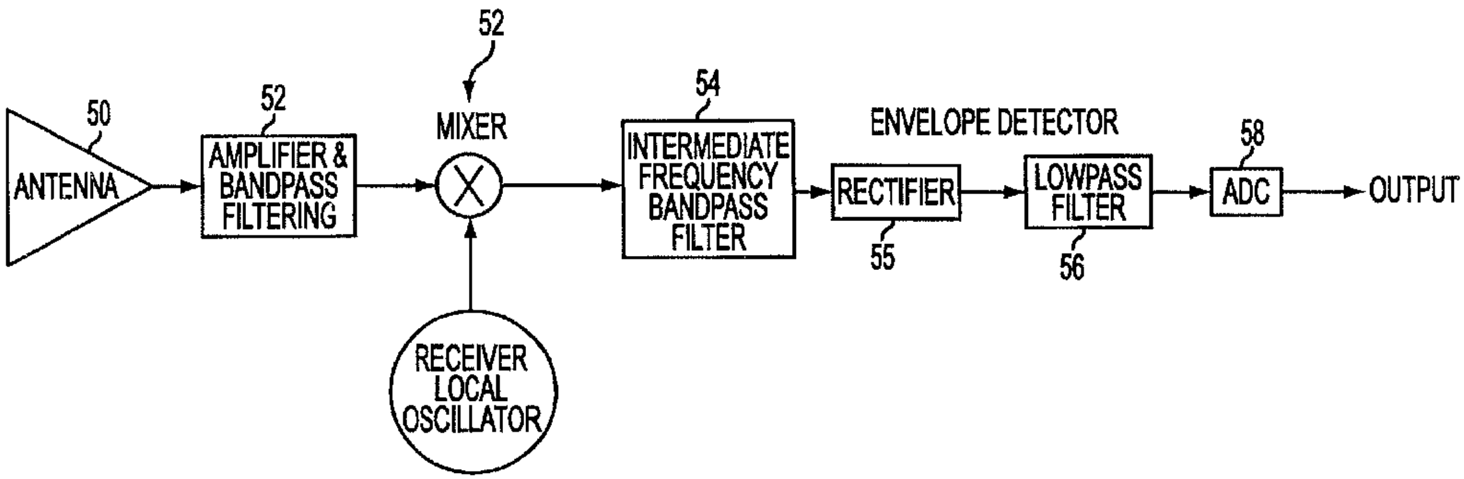
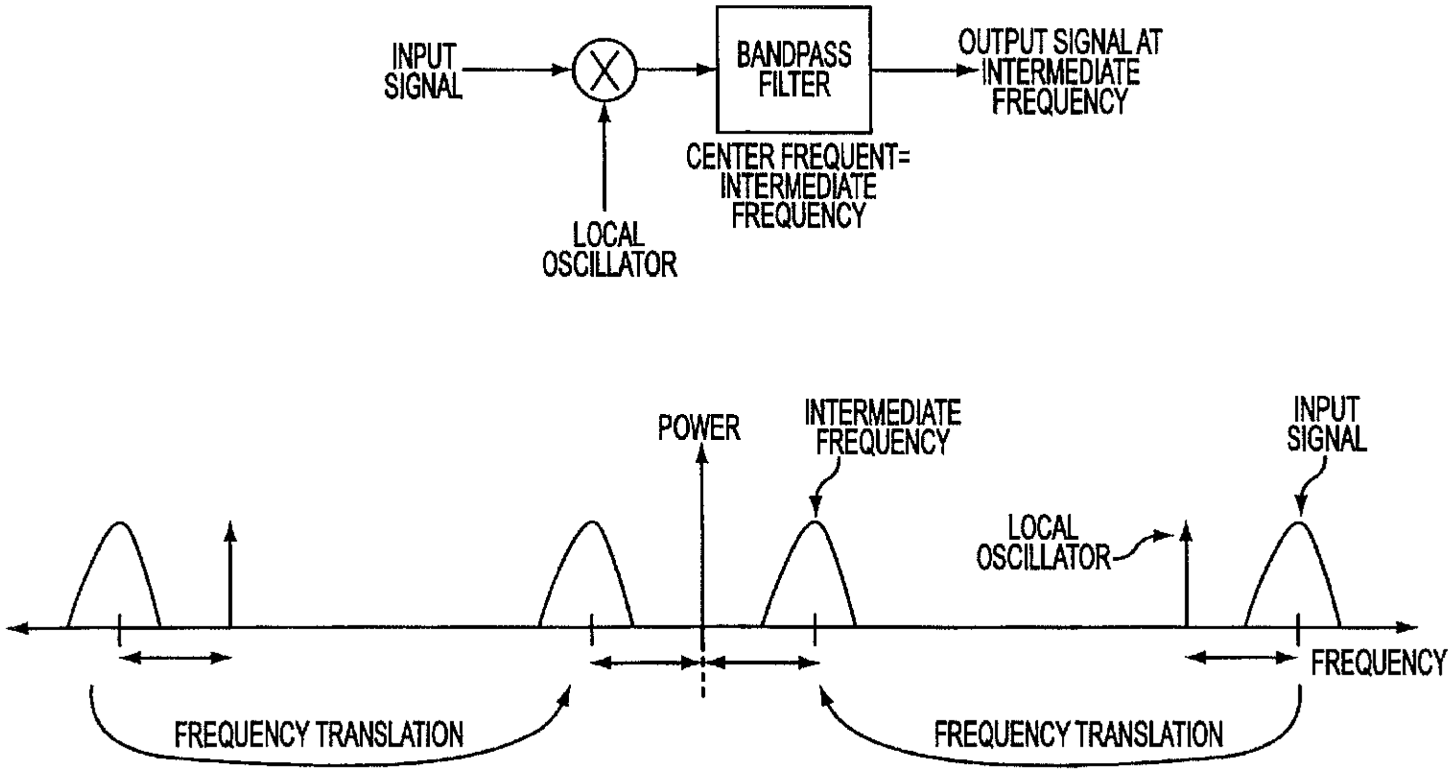


FIG. 5
(PRIOR ART)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BANDPASS FILTER
OUTPUT SIGNAL AT INTERMEDIATE FREQUENCY
CENTER FREQUENT= INTERMEDIATE FREQUENCY
LOCAL OSCILLATOR
POWER
INTERMEDIATE FREQUENCY
INPUT SIGNAL
LOCAL OSCILLATOR
FREQUENCY
FREQUENCY TRANSLATION
FREQUENCY TRANSLATION

FIG. 6

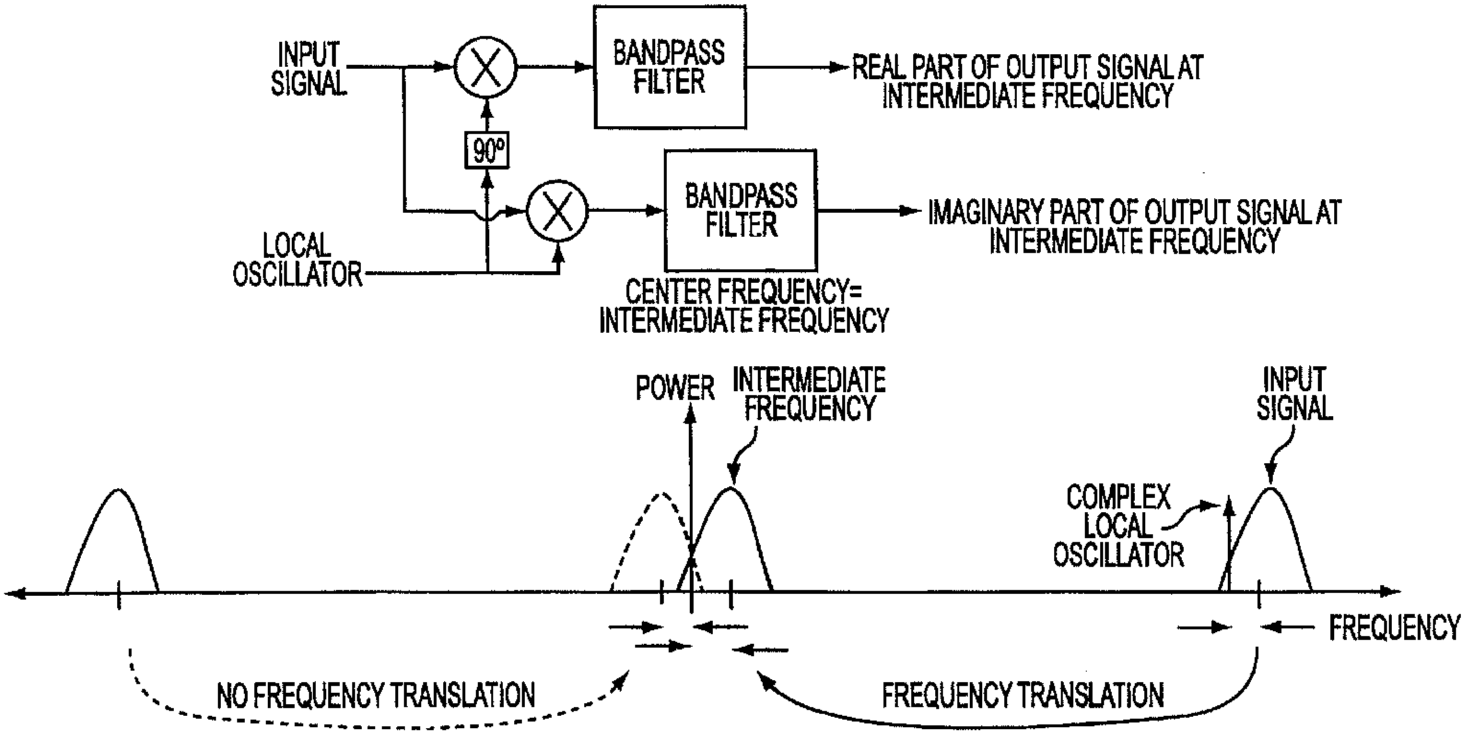
INPUT SIGNAL
BANDPASS FILTER
REAL PART OF OUTPUT SIGNAL AT INTERMEDIATE FREQUENCY
90°
LOCAL OSCILLATOR
BANDPASS FILTER
IMAGINARY PART OF OUTPUT SIGNAL AT INTERMEDIATE FREQUENCY
CENTER FREQUENCY= INTERMEDIATE FREQUENCY
POWER
INTERMEDIATE FREQUENCY
INPUT SIGNAL
COMPLEX LOCAL OSCILLATOR
FREQUENCY
NO FREQUENCY TRANSLATION
FREQUENCY TRANSLATION

FIG. 7

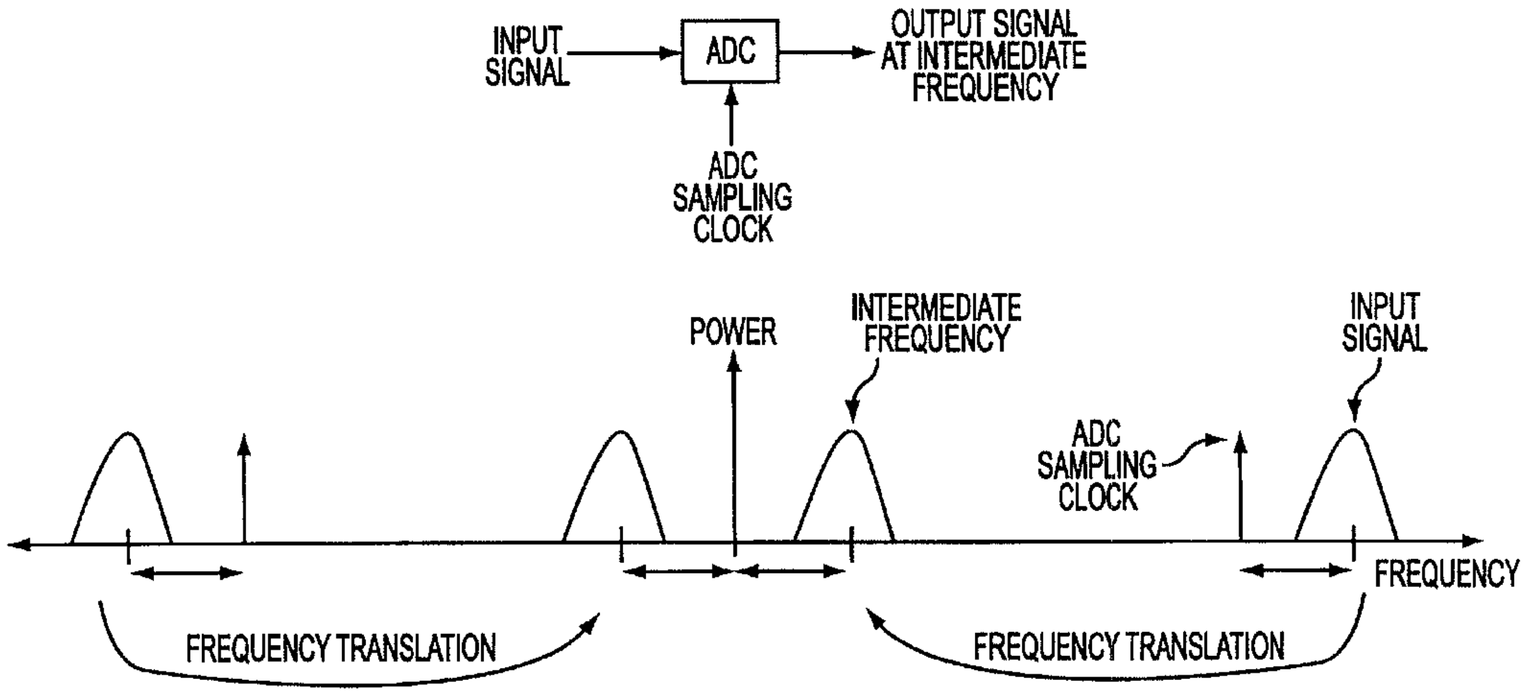
INPUT SIGNAL
ADC
OUTPUT SIGNAL AT INTERMEDIATE FREQUENCY
ADC SAMPLING CLOCK
POWER
INTERMEDIATE FREQUENCY
INPUT SIGNAL
ADC SAMPLING CLOCK
FREQUENCY
FREQUENCY TRANSLATION
FREQUENCY TRANSLATION

FIG. 8

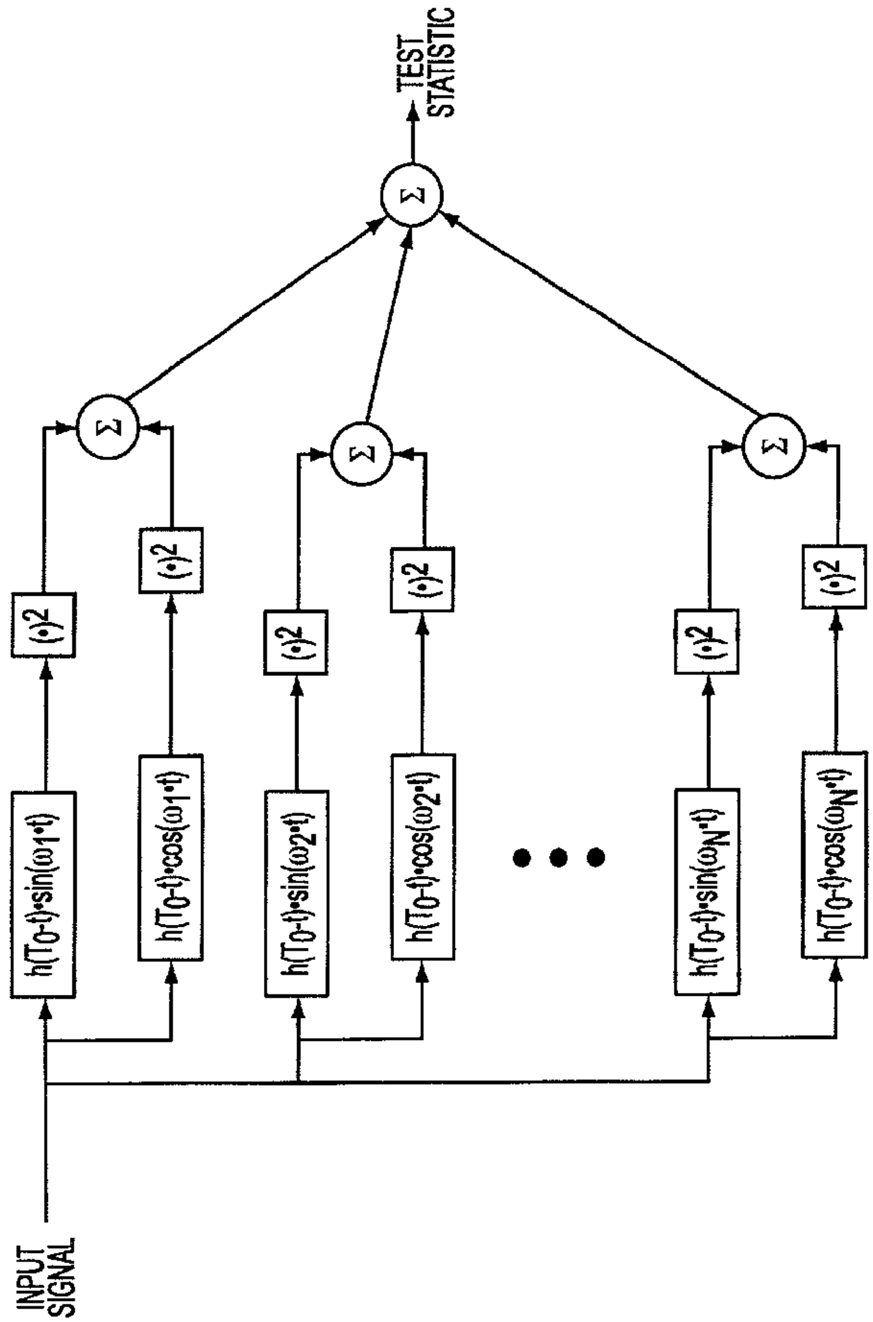
TEST STATISTIC
Σ
Σ
Σ
Σ
(•)2
(•)2
(•)2
(•)2
(•)2
(•)2
h(T0-t)•sin(ω1•t)
h(T0-t)•cos(ω1•t)
h(T0-t)•sin(ω2•t)
h(T0-t)•cos(ω2•t)
h(T0-t)•sin(ωN•t)
h(T0-t)•cos(ωN•t)
INPUT SIGNAL

FIG. 9

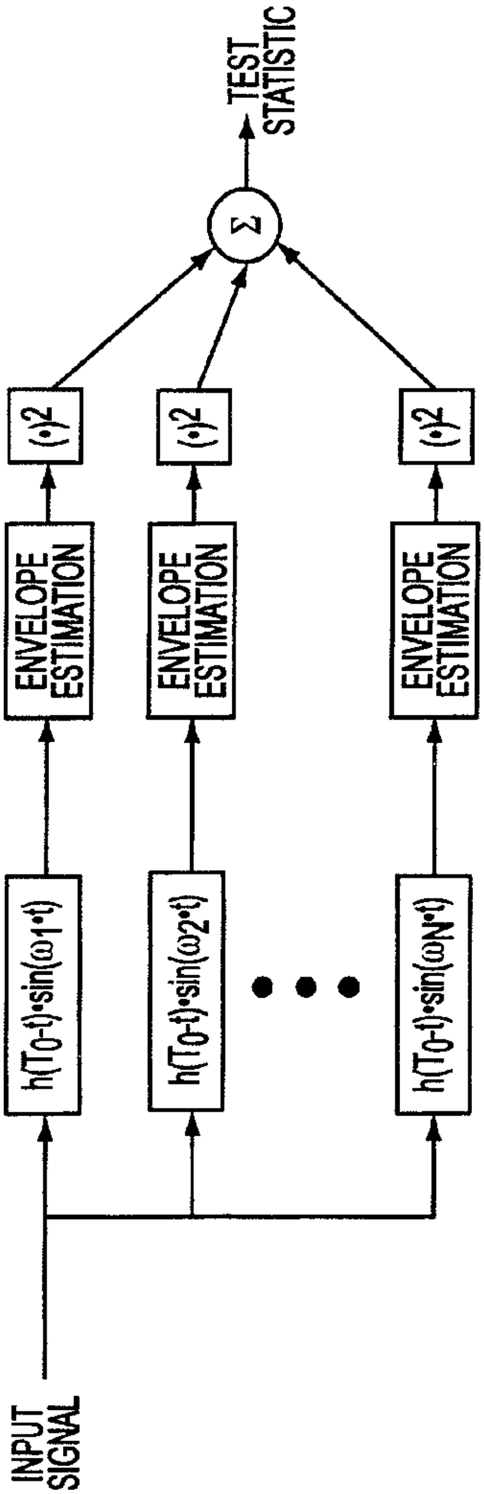
TEST STATISTIC
Σ
(•)2
(•)2
(•)2
ENVELOPE ESTIMATION
ENVELOPE ESTIMATION
ENVELOPE ESTIMATION
h(T0-t)•sin(ω1•t)
h(T0-t)•sin(ω2•t)
h(T0-t)•sin(ωN•t)
INPUT SIGNAL

FIG. 10

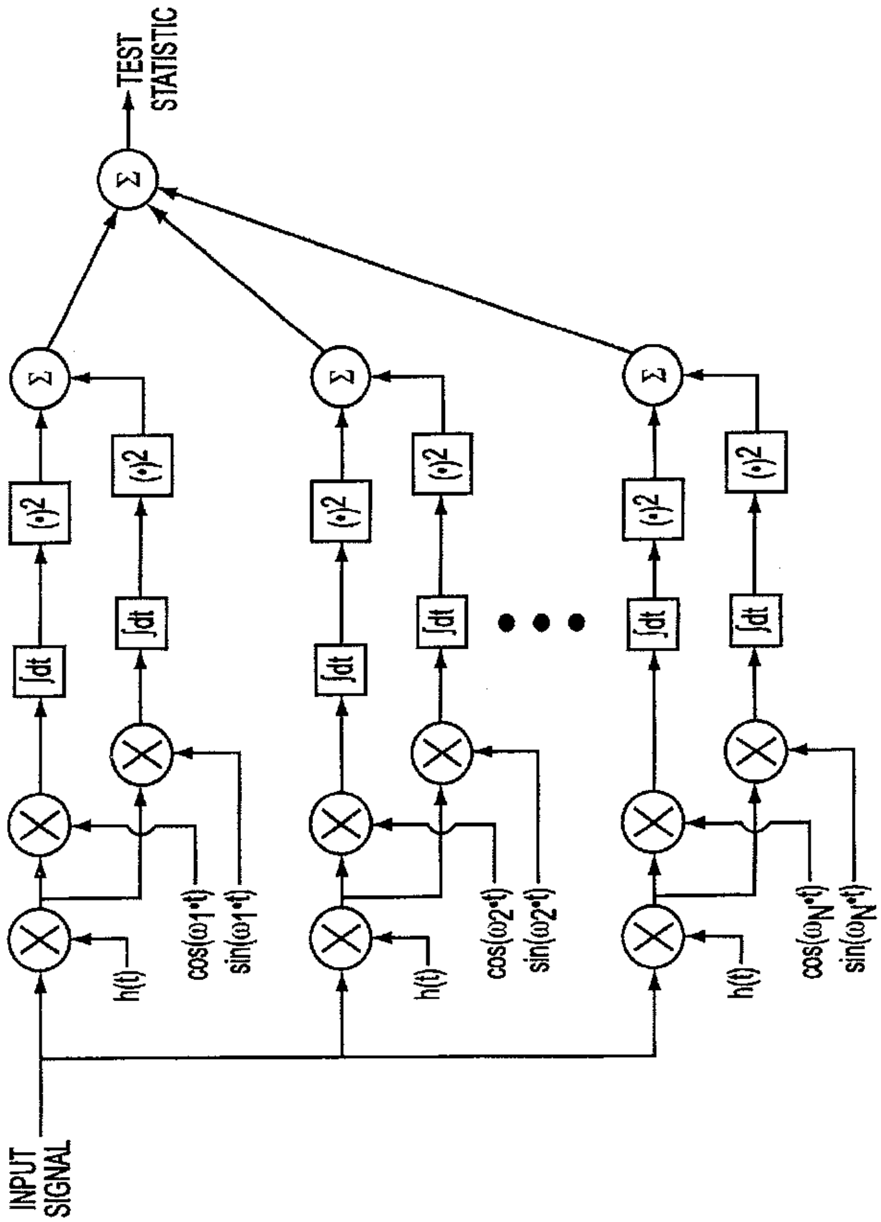
INPUT SIGNAL
TEST STATISTIC
h(t)
cos(ω1•t)
sin(ω1•t)
cos(ω2•t)
sin(ω2•t)
cos(ωN•t)
sin(ωN•t)
∫dt
(•)2
Σ

FIG. 11

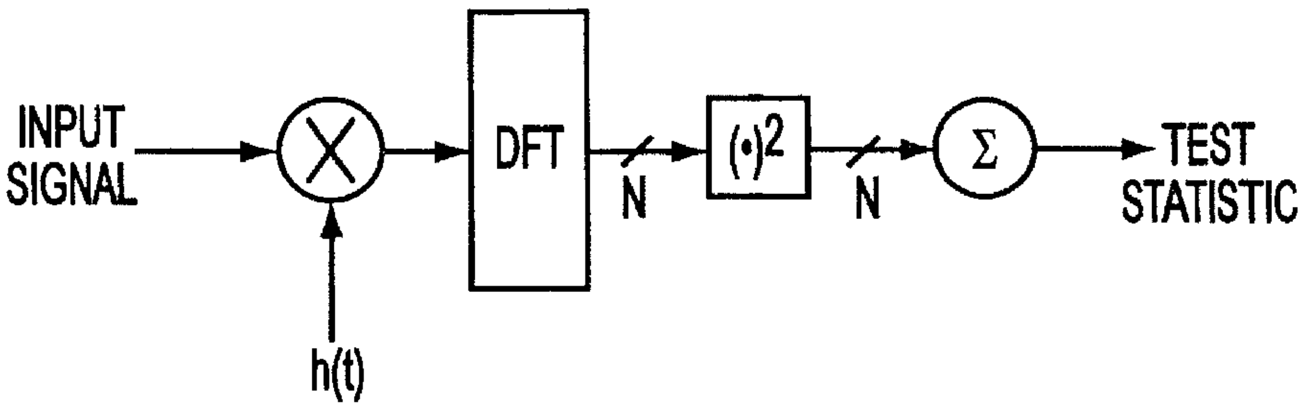

FIG. 12

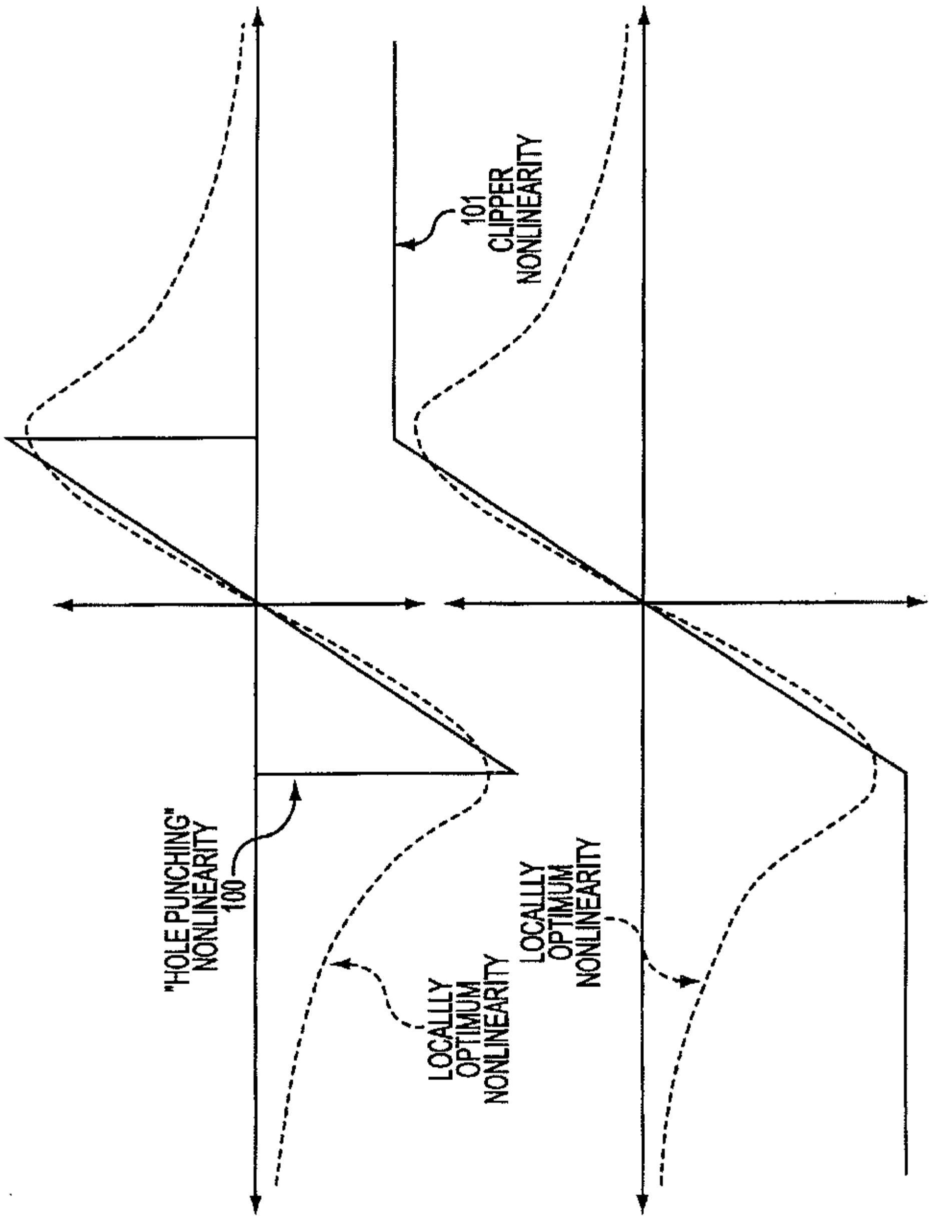
"HOLE PUNCHING" NONLINEARITY
100
LOCALLLY OPTIMUM NONLINEARITY
LOCALLLY OPTIMUM NONLINEARITY
101
CLIPPER NONLINEARITY

FIG. 13

DIGITAL DETECTION FILTERS FOR ELECTRONIC ARTICLE SURVEILLANCE

CROSS REFERENCES TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/278,805, filed Mar. 26, 2001.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

BACKGROUND OF THE INVENTION

1. Field of the Invention

This application relates to digital implementation of electronic article surveillance (EAS) detection filtering, and more particularly to detection filtering in pulsed EAS systems.

2. Description of the Related Art

EAS systems, such as disclosed in U.S. Pat. Nos. 4,622,543, and 6,118,378 transmit an electromagnetic signal into an interrogation zone. EAS tags in the interrogation zone respond to the transmitted signal with a response signal that is detected by a corresponding EAS receiver. Previous pulsed EAS systems, such as ULTRA*MAX sold by Sensormatic Electronics Corporation, use analog electronics in the receiver to implement detection filters with either a quadrature demodulation to baseband or an envelope detection from an intermediate frequency conversion. The EAS tag response is a narrow band signal, in the region of 58000 hertz, for example.

An EAS tag behaves as a second order resonant filter with response

$$s(t)=A\cdot e^{-\alpha\cdot t}\cdot\sin(2\cdot\pi\cdot f_0\cdot t+\theta),$$

where A is the amplitude of the tag response, f_0 is the natural frequency of the tag, and α is the exponential damping coefficient of the tag. The natural frequency of the tag is determined by a number of factors, including the length of the resonator and orientation of the tag in the interrogation field, and the like. Given the population of tags and possible trajectories through the interrogation zone, the natural frequency is a random variable. The probability distribution of the natural frequency has a bell shaped curve somewhat similar to Gaussian. For simplifying the receiver design it may be assumed uniform without a great loss in performance. Its distribution is assumed to be bounded between some minimum and maximum frequencies, f_{min} and f_{max}, respectively.

The exponential damping coefficient α, in effect, sets the bandwidth of the tag signal. Nominal values for α are around 600 with magnetomechanical or acousto-magnetic type tags. On the other hand, for ferrite tags cc will be much larger, on the order of 1200 to 1500.

The phase of the tag response depends on the transmit signal and many of the same parameters as the natural frequency. The transmit signal determines the initial conditions on the tag when the transmitter turns off. This sets the phase of the response as it goes through its natural response. The amplitude of the tag's response is dependent on all of the same parameters: orientation and position in the field, physics of the tag, etc.

Pulse EAS systems, such as ULTRA*MAX systems, operating around 60000 Hz preside in a low frequency atmospheric noise environment. The statistical characteristic of atmospheric noise in this region is close to Gaussian, but somewhat more impulsive, e.g., a symmetric α-stable distribution with characteristic exponent near, but less than, 2.0. In addition to atmospheric noise, the 60000 hertz spectrum is filled with man made noise sources in a typical office/retail environment. These man made sources are predominantly narrow band, and almost always very non-Gaussian. When many of these sources are combined with no single dominant source, the sum approaches a normal distribution due to the Central Limit Theorem. The classical assumption of detection in additive white Gaussian noise is used herein. The "white" portion of this assumption is reasonable since the receiver input bandwidth of 3000 to 5000 hertz is much larger than the signal bandwidth. The Gaussian assumption is justified as follows.

Where atmospheric noise dominates the distribution is known to be close to Gaussian. Likewise, where there are a large number of independent interference sources the distribution is close to Gaussian due to the Central Limit Theorem. If the impulsiveness of the low frequency atmospheric noise were taken into account, then the locally optimum detector could be shown to be a matched filter preceded by a memoryless nonlinearity (for the small signal case). The optimum nonlinearity can be derived using the concept of "influence functions". Although this is generally very untractable, there are several simple nonlinearities that come close to it in performance. To design a robust detector some form of nonlinearity must be included.

When there is a small number of dominant noise sources we include other filtering, prior to the detection filters, to deal with these sources. For example, narrow band jamming is removed by notch filters or a reference based LMS canceller. After these noise sources have been filtered out, the remaining noise is close to Gaussian.

Referring to FIG. **1**, when the signal of interest is completely known a matched filter is the optimum detector. In our case, say we knew the resonant frequency of the tag and its precise phase angle when ringing down. The signal we're trying to detect is

$$s(t)=A\cdot e^{-\alpha\cdot t}\cdot\sin(2\cdot\pi\cdot f_0\cdot t+\theta).$$

Then the matched filter is simply the time reversed (and delayed for causality) signal, $s(T_r-t)$ at **2**. The matched filter output is sampled at **4** at the end of the receive window, T_r, and compared to the threshold at **6**. A decision signal can be sent depending on the results of the comparison to the threshold. The decision can be a signal to sound an alarm or to take some other action. Note that we do not have to know the amplitude, A. This is because the matched filter is a "uniformly most powerful test" with regard to this parameter. This comment applies to all the variations of matched filters discussed below.

Referring to FIG. **2**, when the signal of interest is completely known except for its phase θ, then the optimum detector is the quadrature matched filter (QMF). QMF is also known as noncoherent detection, since the receiver is not phase coherent with the received signal. On the other hand, the matched filter is a coherent detector, since the phase of the receiver is coherent with the received signal. The receive signal r(t) which includes noise and the desired signal s(t) is filtered by $s(T_r-t)$ at **8** as in the matched filter, and again slightly shifted in phase by $\pi/2$ at **10**. The outputs of **8** and **10** are each squared at **12**, combined at **14**, sampled at **16**, and compared to the threshold at **18**.

Referring to FIG. **3**, when the signal of interest is completely known except for its frequency f_n and phase θ, then

the optimum detector is a bank of quadrature matched filters (QMFB). A quadrature matched filter bank can be implemented as a plurality of quadrature matched filters **20**, **22**, **24**, and **26**, which correlate to quadrature matched filters with center frequencies of f_1, f_2 through f_n, respectively. The outputs of the quadrature matched filters are summed at **28**, sampled at **29** and compared to a threshold at **30**.

Referring to FIG. **4** a block diagram of a conventional analog EAS receiver is illustrated. The antenna signal **32** passes through a gain and filtering stage **34** with center frequency equal to the nominal tag frequency and bandwidth of about 3000 hertz, for example. Following this, the signal is demodulated to baseband with a quadrature local receive oscillator **36**. The oscillator frequency may or may not be matched precisely to the transmit frequency. Furthermore, the oscillator phase is not necessarily locked to the transmit oscillator's phase.

The in-phase (I) and quadrature-phase (Q) baseband components are subsequently lowpass filtered by the in-phase **38** and quadrature-phase **40** baseband filters, respectively. This serves to remove the double frequency components produced by the mixing process, as well as further reduces the detection bandwidth. These baseband filters are typically 4^{th} order analog filters, e.g., Butterworth and Chebychev type.

The outputs of the baseband filters **38**, and **40** are passed through rectifiers **42** and **44**, respectively, which removes the sign information from the I and Q components. The outputs of the rectifiers, are sampled by ADC **46** and **48**, respectively, at the end of the receive window and passed into the microprocessor, where the I and Q components are squared and summed together to produce a noncoherent detection statistic.

Referring to FIG. **5**, a block diagram of an alternate analog EAS receiver is illustrated. The antenna signal **50** passes through a gain and filtering stage **52** with center frequency equal to the nominal tag frequency and bandwidth of about 5000 hertz, for example. Following this, the signal is modulated to an intermediate frequency (IF) of approximately 10000 hertz with a local receive oscillator at **52**. The IF signal is filtered by an IF bandpass filter **54** with bandwidth of approximately 3000 hertz to remove off frequency products from the mixer and further reduce bandwidth for the detector.

The filtered IF signal then passes through an envelope detector, which in this case is the combination of a rectifier **55** and lowpass filter **56**. The output of the envelope detector is sampled by an ADC **58** and passed to the processor for detection processing. Note that envelope detection removes the phase of the receive signal. In fact, it can be shown that envelope detection is simply a different implementation of a quadrature detector, and thus it is noncoherent.

The problem presented was to design a cost-effective system, which would more reliably detect a tag response in the presence of noise. The noise environment is assumed to be close to Gaussian with much wider bandwidth than the tag signal. Some environments may include narrow band interference from electronic equipment.

BRIEF SUMMARY OF THE INVENTION

The present invention provides, in a first aspect, a system and method, using a quadrature matched filter bank, to digitally detect a signal from an electronic article surveillance tag. The system and method including: filtering using a detection filter pair comprised of $h(T_0-t)\cdot\sin(\omega\cdot t)$ and $h(T_0-t)\cdot\cos(\omega\cdot t)$, where the envelope $h(T_0-t)$ contains preselected time and frequency domain properties according to the signal to be detected; squaring the output of each of the filters; summing the squared outputs of each of the filter pairs to provide a test statistic for detection of the tag signal.

The system and method further including a plurality of the filter pairs wherein each pair is at a frequency ω_n for $1 \leqq n \leqq N$, where N is selected to cover the range of uncertainty of the signal to be detected, and summing each of the squared and summed results of each of the filter pairs to provide the test statistic for detection of the tag signal. Each of the filter pairs can be matched to the response signal from the electronic article surveillance tag wherein the envelope $h(T_0-t)$ is the time reversed version of the signal to be detected.

In a second aspect, a system and method, using a quadrature matched filter bank with envelope estimation, for detecting the signal from an electronic article surveillance tag. The system and method including: filtering using a filter comprised of $h(T_0-t)\cdot\sin(\omega_n\cdot t)$ wherein the envelope $h(T_0-t)$ contains preselected time and frequency domain properties according to the signal to be detected; envelope detecting of the output of the filter; and, squaring the output of the envelope detection to provide a test statistic for detection of the tag signal.

The system and method further including a plurality of the filters wherein each filter is at a frequency ω_n for $1 \leqq n \leqq N$, where N is selected to cover the range of uncertainty of the signal to be detected; and, then summing the squared output of the plurality of filters to provide the test statistic for detection of the tag signal. Each of the filters can be matched to the response signal from the electronic article surveillance tag wherein the envelope $h(T_0-t)$ is the time reversed version of the signal to be detected.

In a third aspect, a system and method, using a bank of correlation receivers, for detecting a signal from an electronic article surveillance tag. The system and method including: a correlation receiver that mixes a received signal with an envelope $h(t)$ and a pair of local oscillators $\cos(\omega\cdot t)$ and $\sin(\omega\cdot t)$; integrating the mixed signal over the sampling period T_0; squaring the integrated output; summing the squared output for each of the pair of local oscillators to provide a test statistic for detection of the tag signal.

The system and method further including a plurality of the correlation receivers where the local oscillators $\cos(\omega_n\cdot t)$ and $\sin(\omega_n\cdot t)$ are at frequency ω_n for $1<n<N$, where N is selected to cover the range of uncertainty of the signal to be detected; and, summing the output of the plurality of correlation receivers to provide the test statistic for detection of the tag signal.

In a fourth aspect, the system and method of the third aspect where the local oscillators and the integration comprise a discrete Fourier transform

Objectives, advantages, and applications of the present invention will be made apparent by the following detailed description of embodiments of the invention.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. **1** is a block diagram of a conventional matched filter detector.

FIG. **2** is a block diagram of a conventional quadrature matched filter detector.

FIG. **3** is a block diagram of a conventional implementation of a bank of the quadrature matched filters shown in FIG. **2**.

FIG. **4** is a block diagram of a conventional analog EAS receiver.

FIG. 5 is a block diagram of an alternate conventional analog EAS receiver.

FIG. 6 is a block diagram showing frequency conversion for non-overlapping intermediate frequencies for the present invention.

FIG. 7 is a block diagram showing frequency conversion for overlapping intermediate frequencies for the present invention.

FIG. 8 is a block diagram showing frequency conversion and translation using an ADC for non-overlapping intermediate frequencies for the present invention.

FIG. 9 is a block diagram showing one embodiment for direct implementation of the quadrature matched filter bank of the present invention.

FIG. 10 is a block diagram showing implementation of the quadrature matched filter bank of the present invention using envelope detection.

FIG. 11 is a block diagram showing implementation of the quadrature matched filter bank of the present invention as a bank of correlation receivers.

FIG. 12 is a block diagram showing implementation of the quadrature matched filter bank of the present invention as a discrete Fourier transform.

FIG. 13 is a plot showing the sub-optimum nonlinearities selected for the nonlinear filter that precede the quadrature matched filter bank of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The following describe the basic implementation of various components needed for implementing an EAS receiver in digital hardware or software. Local oscillators are a fundamental part of most receiver architectures. There are several ways to implement them digitally. When the sampling rate is a multiple of the oscillator frequency one can directly store a sampled version of one period, then repeatedly read from the table to generate a continuous oscillator signal. If the sampling frequency is not a multiple of the oscillator frequency, the frequency needs to be programmable, or multiple frequencies are needed, then there are two common approaches. One is to store a much finer sampling of the oscillator sinusoid, then use a variable phase step size through the table to change the frequency. If very fine frequency resolution is required the sinusoid table can become too large. In this case, the common trigonometric identities cos(A+B)=cos(A)cos(B)−sin(A)sin(B) and sin (A+B)=sin(A)cos(B)+cos(A)sin(B) may be used to generate a much finer phase step using two tables: a coarse sinusoid table and a fine sinusoid table. Other variations on these schemes are possible, but the basic ideas are the same.

Signal modulators are, in the simplest case, simple multipliers that multiply two signals together. This is often a difficult thing to accomplish in analog hardware, so shortcuts are used, such as chopper modulators, etc. However, in a digital implementation it is possible to directly implement the signal multiplication.

Digital implementations of linear filters are divided into two broad classes: finite impulse response filters, and infinite impulse response filters. In analog circuitry it is usually only possible to implement infinite impulse response filters, with the exception of specialized devises such as surface acoustic wave (SAW) filters, which at 58 kHz would be truly enormous.

In general, finite impulse response (FIR) filters can be implemented using only the input signal and delayed versions of the input signal. There is a wide range of references available for designing/implementing FIR filters and one skilled in the art can do so.

Infinite impulse response (IIR) filters must use, in addition to the input signal, copies of the output signal or internal state variables to be implemented. Again, there is a wide range of references available for designing/implementing IIR filters and one skilled in the art can do so.

A common noncoherent receiver implementation will use envelope detection. This can be accomplished using Hilbert transform algorithms implemented digitally. This gives a precise estimate of the waveform envelope. By designing a Hilbert transform FIR filter it is possible to get frequency selectivity together with envelope estimation. Another approach that is a coarser approximation, particularly useful for narrow band signals, is to choose the sampling rate so that a 90 degree phase shift (at the center frequency) is approximately an integer number of samples. Then the quadrature signals are simply an integer number of samples shift.

The following describe the disclosed invention including various embodiments for digital implementation of detection filters for pulsed EAS systems. The embodiments show implementations for the frequency conversion and for the detection filters. A fundamental assumption to all of the following is that the receive signal has been sampled by an analog-to-digital converter (ADC). Thus, all of the processing takes place in the sampled time "digital" domain as opposed to continuous time analog domain. One exception to this discussed below is where the concept of sub-sampling of the signal is disclosed, in which case the ADC sampling actually is the frequency conversion.

Referring to FIGS. 6 and 7, frequency conversion will typically be used to translate the receive signal lower in frequency to ease some other aspect of processing, typically memory or computational consumption. This is because as the center frequency of the signal is reduced, the sampling frequency can also be reduced. Two situations are possible: non-overlapping intermediate frequencies or overlapping intermediate frequencies.

FIG. 6 shows an example in which the output intermediate frequencies do not overlap. In this case, the receive local oscillator can be real valued and the output can be real valued.

FIG. 7 shows an example in which the output intermediate frequencies do overlap. In this case, the receive local oscillator must be complex valued and the output will be complex valued.

Referring to FIG. 8, if little or no signal intermediate frequency overlap occurs an ADC can be used to simultaneously sample and down convert the data. Aliasing distortion is possible if a significant amount of noise occurs at the image frequency. In addition, the lower sampling rates may be less effective for filtering impulsive noise.

The following describes digital implementation of the optimum detector as a quadrature matched filter bank (QMFB). The implementations are independent of the frequency of operation, i.e., directly at passband, at an intermediate frequency, or at baseband. Only the frequencies of the local oscillators change. Note that the combining of the QMF's is shown as uniform summation, which is appropriate for a uniform probability distribution of the natural frequencies. If a non-uniform distribution is assumed, then the outputs of the QMF's must be weighted appropriately. Also, the difference between α in ferrite tags and regular magnetomechanical EAS tags must be accounted for. This

can be accomplished by one of three approaches: manual selection of the matched envelope function, calculating the QMFB with both envelope functions and selecting the output with the highest (normalized) energy, or choosing one envelope function as a suboptimum compromise for both types of tag environments.

Referring to FIG. 9, a direct implementation of the QMFB is illustrated. The matched filters "$h(T_0-t)\cdot\sin(\omega_n\cdot t)$" and "$h(T_0-t)\cdot\cos(\omega_n\cdot t)$" are in phase quadrature to one another. The envelope "$h(T_0-t)$" is the time reversed version of the nominal envelope of the signal to be detected. The time T_0 is the sampling time at the output of the detection filters. The frequencies ω_n for $1 \leqq n \leqq N$ are chosen to cover the range of uncertainty of the tag signal. In practice the window function "$h(T_0-t)$" may be chosen based on a number of criteria and constraints, including spectral resolution, minimizing energy due to transmitter ringdown, or simply minimizing complexity of the receiver. The matched filters would generally be implemented as FIR filters, since it would be difficult to control to the and amplitude using a IIR filter design.

Referring to FIG. 10, an implementation of the QMFB using envelope detection (estimation) is illustrated. In this implementation, only one matched filter is required. The matched filter must be within a constant phase shift. Envelope detection is used to extract the individual QMF statistics.

Referring to FIG. 11, an implementation as a bank of correlation receivers is illustrated. The incoming signal is modulated with the matched envelope and local oscillators, then integrated to the sampling instant T_0. The integrators are implemented digitally as summations, scaled by the sampling period. This implementation is typically better than the previous two because only one envelope need be stored, and in fact the envelope modulation need only be calculated once. The local oscillator modulation and integration are very simple structure to implement. This is generally much better than a bank of FIR filters.

Referring to FIG. 12, an implementation as a discrete Fourier transform (DFT) is illustrated. This is a direct consequence of the structure shown in FIG. 11. When the sampling rate and frequency resolution of the local oscillators are chosen appropriately, the DFT can be implemented as a Fast Fourier transform (FFT), an extremely efficient digital implementation of the QMFB. Other variations are possible, such as Zoom FFTs when the frequency band of interest is narrower. However, the basic concept is the same.

Referring to FIG. 13, many of the noise environments in which EAS systems are installed have some level of impulsive noise. In such environments the QMFB must be preceded by a nonlinearity. The locally optimum nonlinearity is given in terms of influence functions. However, it is not practical, or often possible since many of these waveforms cannot be generated in closed form, to use the actual optimum nonlinearity. Therefore we resort to suboptimum nonlinearities, as illustrated in FIG. 13. The "hole punch" nonlinearity **100** generally has the highest performance, but when auxiliary detection criteria such as frequency or phase estimates are implemented, this nonlinearity has adverse effects. The "clipping" nonlinearity **101** performs better. The threshold for these nonlinearities must be chosen adaptively. If the interest is in locally optimum performance, i.e., detection of weak signals, then the threshold can be chosen at some level above the RMS noise floor. However, if the interest is in detection of strong signals as well, then the threshold must be calculated adaptively from the record of data itself. For example, the RMS level of the first 100 microseconds or so of data is calculated, then the threshold is set at some level above that. In this way, strong tag signals are not excessively trimmed by the nonlinearity.

There are many other possibilities that may be implemented in the digital receiver and which are contemplated by this disclosure, including nonlinear filters, hybrid filters, or nonlinear filtering followed by linear detection filters. These types of configurations may be necessary in impulsive noise environments.

It is to be understood that variations and modifications of the present invention can be made without departing from the scope of the invention. It is also to be understood that the scope of the invention is not to be interpreted as limited to the specific embodiments disclosed herein, but only in accordance with the appended claims when read in light of the forgoing disclosure.

What is claimed is:

1. A digital detector implemented as a quadrature matched filter bank for detecting a response signal from an electronic article surveillance tag, comprising:

a detection filter pair comprised of $h(T_0-t)\cdot\sin(\omega\cdot t)$ and $h(T_0-t)\cdot\cos(\omega\cdot t)$, wherein the envelope $h(T_0-t)$ contains preselected time and frequency domain properties according to the signal to be detected;

means for squaring the output of each of said filters; and

means for summing the squared outputs of each of said filter pairs to provide a test statistic for detection of the tag signal.

2. The digital detector of claim **1** further comprising:

a plurality of said filter pairs wherein each pair is at a frequency ω_n for $1 \leqq n \leqq N$, where N is selected to cover the range of uncertainty of the signal to be detected; and,

means for summing each of the squared and summed results of each of said filter pairs to provide the test statistic for detection of the tag signal.

3. The digital detector of claim **2** wherein each of said filter pairs are matched to the response signal from the electronic article surveillance tag wherein the envelope $h(T_0-t)$ is the time reversed version of the signal to be detected.

4. The digital detector of claim **3** further comprising means for nonlinear filtering prior to said detection filter pair, wherein the nonlinearity of said means for nonlinear filtering is selected from a hole punch or a clipping nonlinearity.

5. A digital detector implemented as a quadrature matched filter bank with envelope estimation for detecting a signal from an electronic article surveillance tag, comprising:

a detection filter comprised of $h(T_0-t)\cdot\sin(\omega\cdot t)$ wherein the envelope $h(T_0-t)$ contains preselected time and frequency domain properties according to the signal to be detected;

means for envelope detection of the output of said filter; and,

means for squaring the output of said envelope detection to provide a test statistic for detection of the tag signal.

6. The digital detector of claim **5** further comprising:

a plurality of said filters wherein each filter is at a frequency ω_n for $1 \leqq n \leqq N$, where N is selected to cover the range of uncertainty of the signal to be detected; and,

means for summing the output of said means for squaring for said plurality of said filters to provide the test statistic for detection of the tag signal.

7. The digital detector of claim 6 wherein each of said filters are matched to the response signal from the electronic article surveillance tag wherein the envelope $h(T_0-t)$ is the time reversed version of the signal to be detected.

8. The digital detector of claim 7 further comprising means for nonlinear filtering prior to said detection filter, wherein the nonlinearity of said means for nonlinear filtering is selected from a hole punch or a clipping nonlinearity.

9. A digital detector implemented as a bank of correlation receivers for detecting a signal from an electronic article surveillance tag, comprising:

a correlation receiver including means for mixing a received signal with an envelope h(t) and a pair of local oscillators $\cos(\omega \cdot t)$ and $\sin(\omega \cdot t)$;

means for integrating the output of said means for mixing over the sampling period T_0;

means for squaring the output of said integration means; and,

means for summing the output of said means for squaring for each of the pair of local oscillators to provide a test statistic for detection of the tag signal.

10. The digital detector of claim 9 further comprising a plurality of said correlation receivers wherein said local oscillators $\cos(\omega_n \cdot t)$ and $\sin(\omega_n \cdot t)$ are at frequency ω_n for $1 \leqq n \leqq N$, where N is selected to cover the range of uncertainty of the signal to be detected; and,

means for summing the output of said plurality of correlation receivers to provide a test statistic for detection of the tag signal.

11. The digital detector of claim 10 wherein said local oscillators and said means for integration comprise a discrete Fourier transform.

12. A method, using a quadrature matched filter bank, for digitally detecting a signal from an electronic article surveillance tag, comprising:

filtering using a detection filter pair comprised of $h(T_0-t)\cdot\sin(\omega \cdot t)$ and $h(T_0-t)\cdot\cos(\omega \cdot t)$, wherein the envelope $h(T_0-t)$ is preselected to contain time and frequency domain properties according to the signal to be detected;

squaring the output of each of said filters;

summing the squared outputs of each of said filter pairs to provide a test statistic for detection of the tag signal.

13. The method of claim 12 further comprising a plurality of said filter pairs wherein each pair is at a frequency ω_n for $1 \leqq n \leqq N$, where N is selected to cover the range of uncertainty of the signal to be detected and summing each of the squared and summed results of each of said filter pairs to provide the test statistic for detection of the tag signal.

14. The method of claim 13 wherein each of said filters are matched to the response signal from the electronic article surveillance tag wherein the envelope $h(T_0-t)$ is the time reversed version of the signal to be detected.

15. The method of claim 14 further comprising, prior to said detection filtering, nonlinear filtering using a nonlinearity selected from a hole punch or a clipping nonlinearity.

16. A method, using a quadrature matched filter bank with envelope estimation, for detecting a signal from an electronic article surveillance tag, comprising:

filtering using a detection filter comprised of $h(T_0-t)\cdot\sin(\omega \cdot t)$ wherein the envelope $h(T_0-t)$ is preselected to contain time and frequency domain properties according to the signal to be detected;

envelope detecting of the output of said filter;

squaring the output of said envelope detection to provide a test statistic for detection of the tag signal.

17. The method of claim 16 further comprising a plurality of said filters wherein each filter is at a frequency ω_n for $1 \leqq n \leqq N$, where N is selected to cover the range of uncertainty of the signal to be detected; and,

summing the squared output of said plurality of filters to provide the test statistic for detection of the tag signal.

18. The method of claim 17 wherein each of said filters are matched to the response signal from the electronic article surveillance tag wherein the envelope $h(T_0-t)$ is the time reversed version of the signal to be detected.

19. The method of claim 18 further comprising, prior to said detection filtering, nonlinear filtering using a nonlinearity selected from a hole punch or a clipping nonlinearity.

20. A method, using a bank of correlation receivers, for detecting a signal from an electronic article surveillance tag, comprising:

in a correlation receiver;

mixing a received signal with a matched envelope h(t) and a pair of local oscillators $\cos(\omega \cdot t)$ and $\sin(\omega \cdot t)$;

integrating the mixed signal over the sampling period T_0;

squaring the output of said integrated signal;

summing the squared output for each of the pair of local oscillators to provide a test statistic for detection of the tag signal.

21. The method of claim 20 further comprsising a plurality of said correlation receivers wherein said local oscillators $\cos(\omega_n \cdot t)$ and $\sin(\omega_n \cdot t)$ are at frequency ω_n for $1 \leqq n \leqq N$, where N is selected to cover the range of uncertainty of the signal to be detected; and,

summing the output of said plurality of correlation receivers to provide the test statistic for detection of the tag signal.

22. The method of claim 21 wherein said local oscillators and said integration comprise a discrete Fourier transform.

* * * * *

US006118378A

United States Patent [19]

Balch et al.

[11] **Patent Number: 6,118,378**

[45] **Date of Patent: Sep. 12, 2000**

[54] **PULSED MAGNETIC EAS SYSTEM INCORPORATING SINGLE ANTENNA WITH INDEPENDENT PHASING**

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[73] Assignee: **Sensormatic Electronics Corporation**, Boca Raton, Fla.

[21] Appl. No.: **08/969,928**

[22] Filed: **Nov. 28, 1997**

[51] **Int. Cl.**[7] **H04Q 1/00**

[52] **U.S. Cl.** **340/572.7**; 343/742; 343/867

[58] **Field of Search** 340/572.7, 10.2; 343/742, 867

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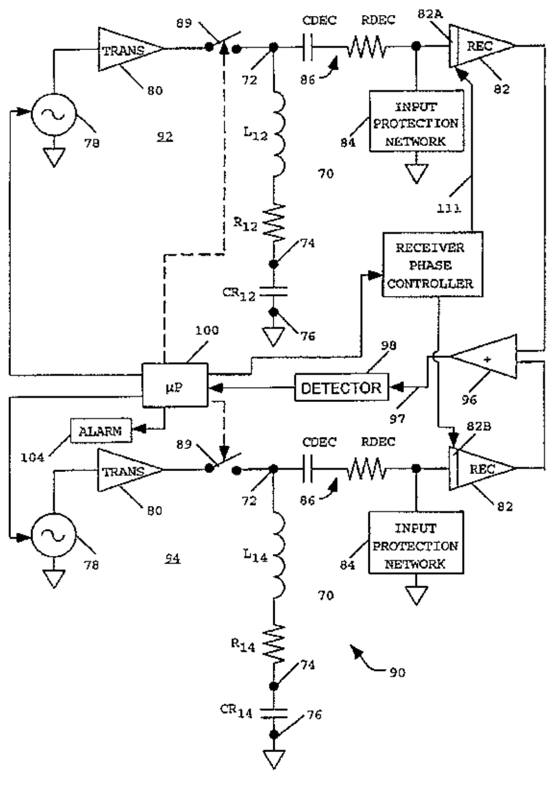
Primary Examiner—Brian Zimmerman
Attorney, Agent, or Firm—Quarles & Brady LLP

[57] **ABSTRACT**

A single antenna transmits and receives signals. The single antenna has first and second antenna loops substantially lying in a common plane and partially overlapping. First and second transceiver circuits are coupled to the first and second antenna loops respectively, for respectively generating in a first mode of operation first and second pulsed magnetic fields together defining an interrogation zone for a marker generating a characteristic response to the magnetic fields in the interrogation zone, and for receiving signals from the interrogation zone in a second mode of operation. The first and second transceiver circuits alternately generate the first and second magnetic fields substantially in phase with one another and substantially out of phase with one another. The partially overlapping antenna loops prevent detuning of the transceivers otherwise resulting from the phase alternating. Each of the first and second transceiver circuits has a phase controllable transmitter section and a phase controllable receiver section. A controller independently phase controls the transmitter and receiver sections. Each receiver section is coupled across the tuned circuit of its respective transceiver circuit.

23 Claims, 3 Drawing Sheets



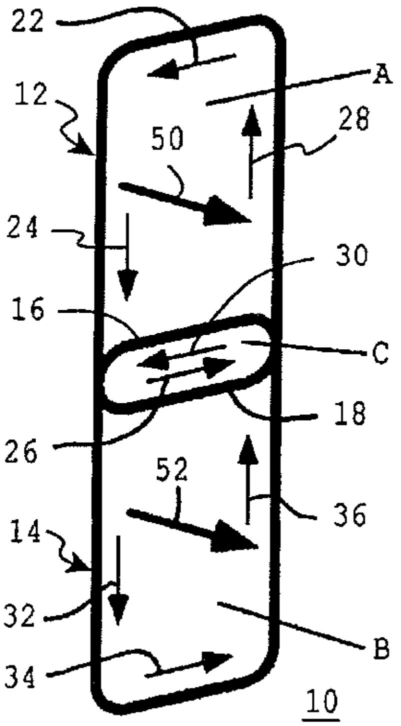


FIG. 1

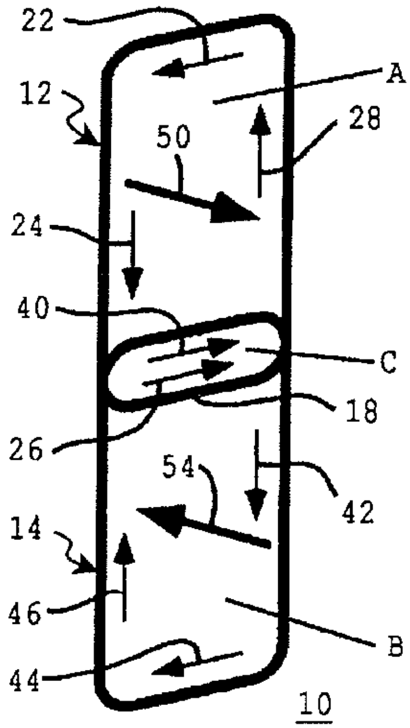


FIG. 2

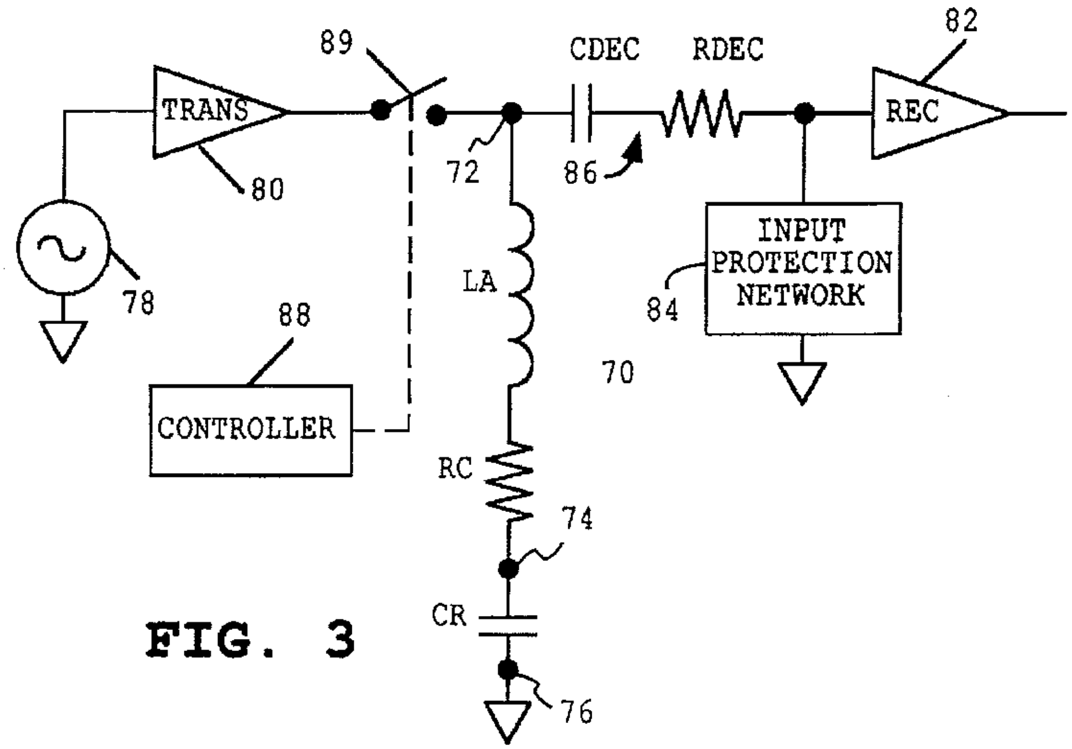
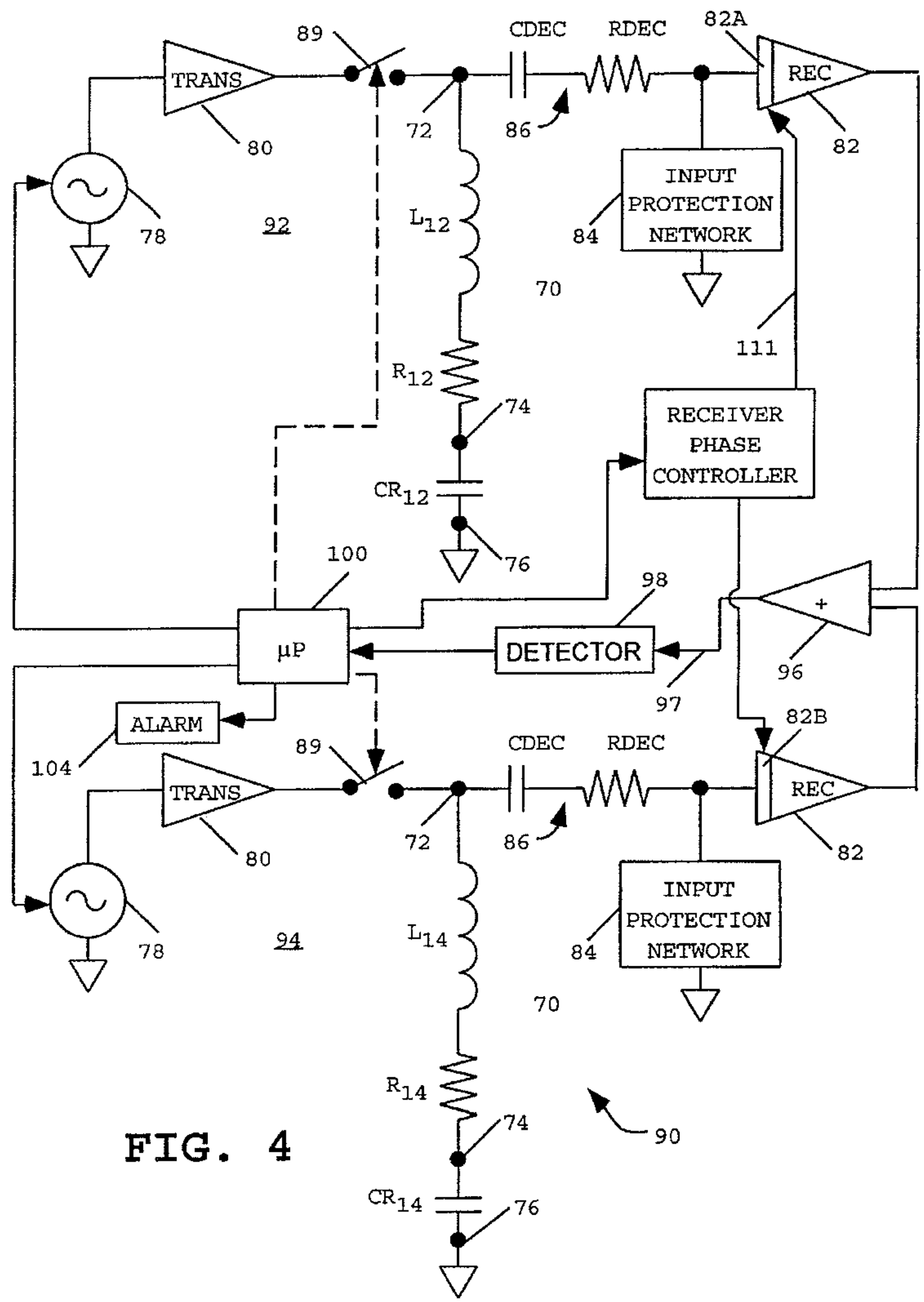


FIG. 3



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RECEIVER PHASE CONTROLLER
CR12
76
100
98
+
μP
DETECTOR
96
97
ALARM
82B
104
89
CDEC
RDEC
TRANS
REC
72
86
80
82
78
94
L14
INPUT PROTECTION NETWORK
84
70
R14
74
90
CR14
76

FIG. 4